Final Report

MONO LAKE WAVE EXPERIMENT: FEASIBILITY STUDY

Contract Nonr 4488(00)

NATIONAL MARINE CONSULTANTS

A DIVISION OF

Interstate ELECTRONICS CORPORATION

ANAHEIM, CALIFORNIA

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Prepared for
Office of Naval Research
Contract Nonr 4488(00)
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Prepared by National Marine Consultants

Approved by

Richard C. Timme, General Manager
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ABSTRACT

The feasibility of conducting experiments during which bomb-wave runup mechanics could be observed and measured has been considered. Investigations indicate that the program, as envisioned, is feasible at Mono Lake.

The following report presents the results of the study regarding:

- Site Selection and Investigation
- Range Instrumentation and Operation
- Cost-Estimate for the Program

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FOREWORD

The following is the final report concerning proposed range operations at Mono Lake, California, and the wave experiment to be conducted at this location.

This report has been prepared by Dwight D. Pollard, Acting Manager, Oceanographic Sciences Department, National Marine Consultants, and under the direction of Dr. Richard E. Kent, Consultant and Project Officer. Specific contributions have been made by National Marine Consultants staff members John Althouse and Homer Sargeant (Instrumentation System), Ken Herkimer (Telemetry), George Wilson (Range Operations), and Donald Bellows (Charge and Instrument Support Systems).

I
INTRODUCTION

A. BACKGROUND INFORMATION

The destructive potential of water waves that can be produced by man-made energy releases has been increased several orders of magnitude with the advent of nuclear technology. Fortunately, the bomb-wave effects problem has been recognized for some time by various Government agencies, with the result that many aspects of the matter have been studied intensively.

Such research has been conducted on both experimental and theoretical planes in an effort to produce reliable wave prediction formulae. These efforts have been valuable in two respects. First, many advances in understanding and describing the pertinent wave mechanics have been made, and second, the inherent complexities of the phenomenon have become recognized more clearly and to some extent, defined.

However, many questions remain unanswered in the general sense, of which the primary example is wave runup on a coastal area. While numerous studies of runup have been conducted, essentially nothing in the way of a breakthrough has been achieved. Perhaps the most notable advance in runup prediction has been the use of high speed computers to print out solutions of theories of rather ancient vintage, and modifications thereof by modern researchers. In this regard, it is somewhat of a paradox that, conceivably, existing theories may describe bomb-wave runup appropriately and all that is required is a demonstration of their validity. (This latter statement implies that bomb waves and seismic sea waves are quite dissimilar.)

As a consequence of this apparent gap in wave-runup knowledge, it would appear highly desirable that a series of controlled high explosive experiments be conducted using as large a yield as feasible. It is expected that such a non-nuclear program could be conducted under a wide range of conditions at a cost markedly less than that involving a series of nuclear tests conducted solely for wave effects.

Some months ago, ONR and DASA convened a meeting at Scripps Institution of Oceanography to discuss directions along which future research effort on the bomb-wave problem should be channeled. At this meeting, it was suggested that DOD contemplate supporting a rather large research program in which large HE yields would be exploded in a protected water area, and the resulting wave runup mechanics observed and measured in all necessary detail.

Shortly thereafter, a preliminary evaluation of the feasibility of the concept (directed exclusively to the site selection problem) was made with promising results.* Subsequently (in July 1963), a proposal to study the feasibility of the program in detail was submitted to ONR. Briefly, the objectives of the proposed study were:

(1) to determine the interest of various Government agencies in the wave runup problem, and to coordinate their possible participation in the proposed program,

(2) to conduct a site selection investigation, and if a feasible site is found,

(3) to establish the experimental design for the proposed project. This involves such items as:

(a) specifying all range instrumentation,

(b) specifying data measurement space-time grids,

(c) detailing mobilization, execution, and rollup operations, and

(d) providing a cost-estimate for the proposed program.

In the fall of 1964 the proposed study was supported by ONR and scheduled for completion on March 31, 1965. The purpose of this report is to present the final results of the study.

B. SUMMARY OF RESULTS

To some extent, the dominant constraint in selecting a site for the proposed experiment was charge size. It was determined that the largest charge that could be reasonably handled would be about 10,000 pounds. This yield would require water depths of approximately 150 feet for detonation in order to produce maximum possible waves.

Additional site requirements are:

(1) low wave background,

(2) low biological background,

(3) accessibility,

(4) remoteness, and

(5) acceptable shoreline topology.

* Mono Lake, California appeared to be the best possible site.

After considerable investigation of the above items, it was concluded that the best available site was Mono Lake, California, shown in figure 1 (this figure is included in the back-cover pocket). Mono Lake has a maximum depth of about 150 feet, has prolonged periods of calm water conditions, is remote in terms of human habitation yet is immediately adjacent to a main highway, has a wide range of shoreline slopes, and is essentially devoid of biological life. Details on the geology, climatology, limnology, and bathymetry of the lake are presented in section II-A of this report.

Early in the feasibility study, wind and wave gauges were installed at Mono Lake at what appeared to be (after a preliminary analysis) the most logical locality for the experiment to take place. Results of this instrumentation are presented in section II-B of this report. A detailed bathymetric survey of the lake proper (figures 2 and 3) was conducted by Naval Ordnance Test Station personnel. Figure 3 (showing bottom topography profile transits and Fastax camera locations) is included in the back-cover pocket. Other specific items of major concern were bottom slope representability (in terms of actual continental conditions) and bottom and shoreline composition. Figure 4 presents a series of lake slopes taken in the selected program area* along with certain Pacific and Atlantic coastal slopes.

As can be seen, the Mono Lake slopes are somewhat steeper than are the Pacific and Atlantic ones. Consequently, it is envisioned that, in addition to the natural slopes, an artificial beach having a lesser slope will be constructed.

The beach material itself is relatively coarse, and at first inspection gave concern about wave energy percolation losses. To evaluate the energy loss, a section of the beach was rendered impermeable, and waves generated to produce a runup on both this modified section and an adjacent non-treated section. It appeared, to all practical intent, that wave runup on the bare beach sand was only slightly less than it was on the impermeable section. Consequently, it was concluded that the percolation would not be a problem in the proposed test area.

A series of calculations of wave signal strengths also were prepared,** using desirable surface zero locations and wave travel transits (figure 3). These data (based more or less upon empirical formulae) indicate that the wave heights at the shoreline of the experimental area produced by a 10,000 pound explosion at the indicated locations would be on the order of six inches or more, and would have periods (of the maximum wave) on the order of 5 to 7 seconds — all of these characteristics being acceptable in the design of the experiment.

In summary, investigations indicate that the program, as envisioned, is feasible at Mono Lake. Wind and wave background measurements still are in progress and will continue through the proposed program.

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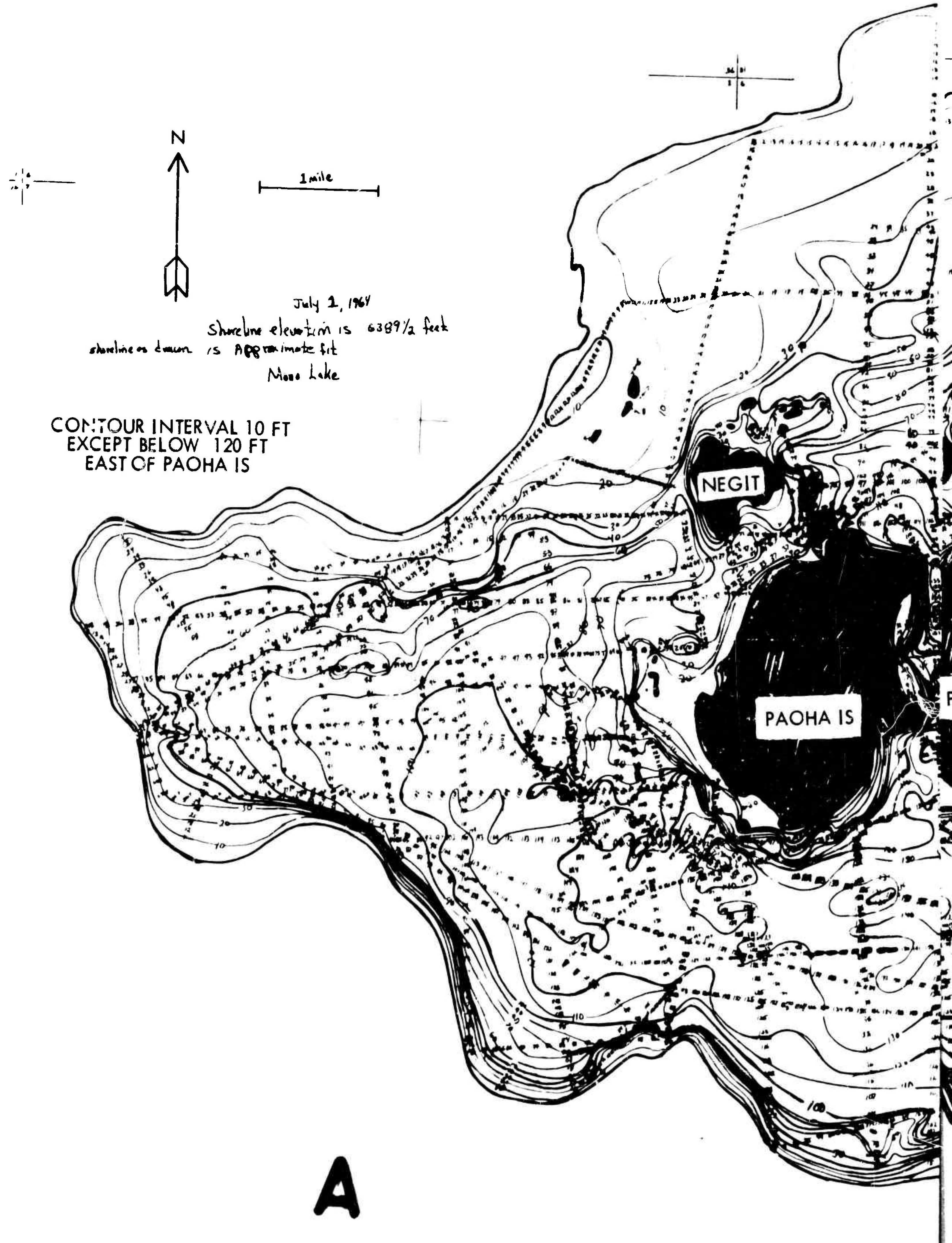
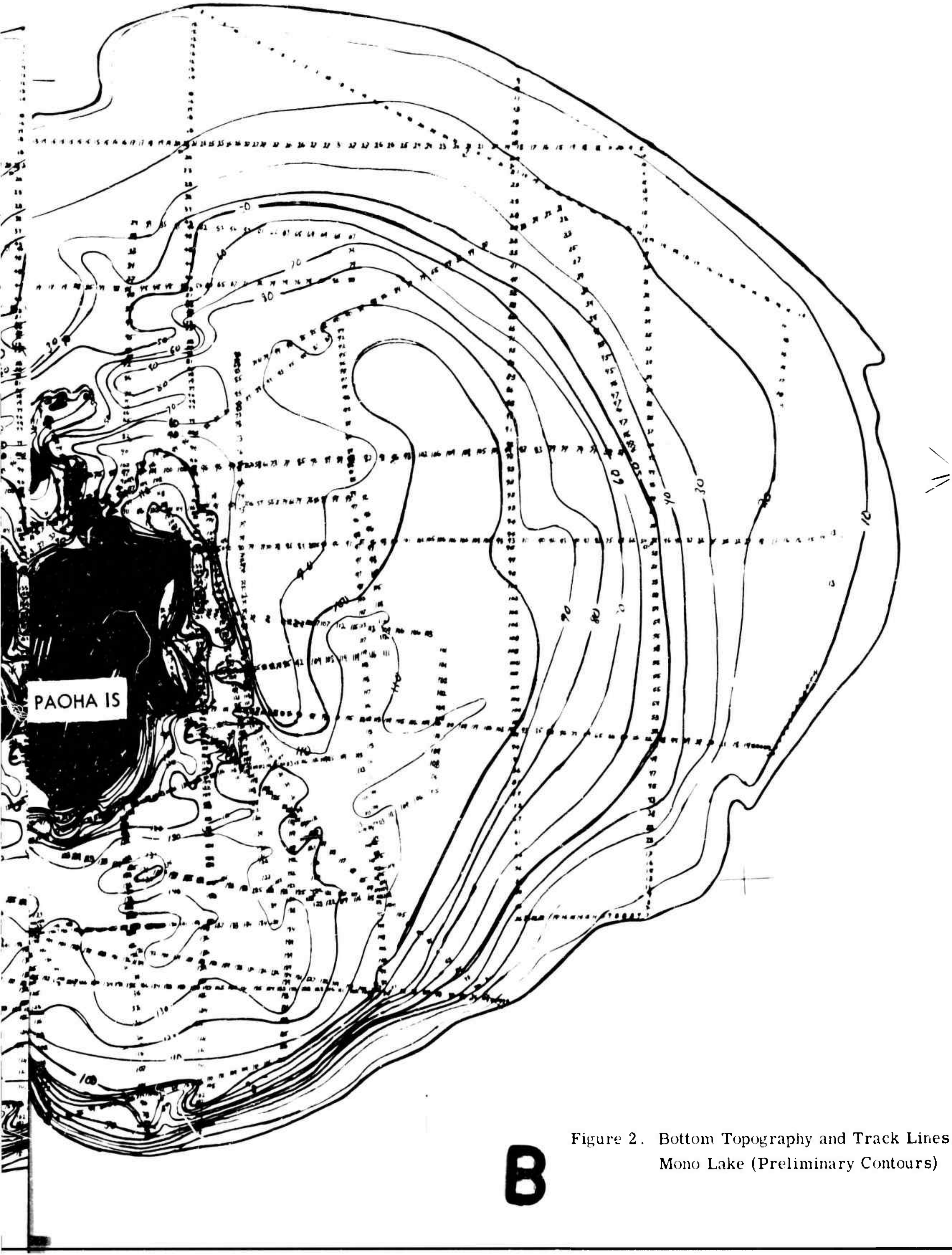
* Transits as shown on figure 3.

** Dr. W. Van Dorn, Scripps Institute of Oceanography.



N
1 mile
July 1, 1964
Shoreline elevation is 6389½ feet
shoreline as drawn is approximate fit
Mono Lake
CONTOUR INTERVAL 10 FT
EXCEPT BELOW 120 FT
EAST OF PAOHA IS
NEGIT
PAOHA IS
A



B

Figure 2. Bottom Topography and Track Lines,
Mono Lake (Preliminary Contours)

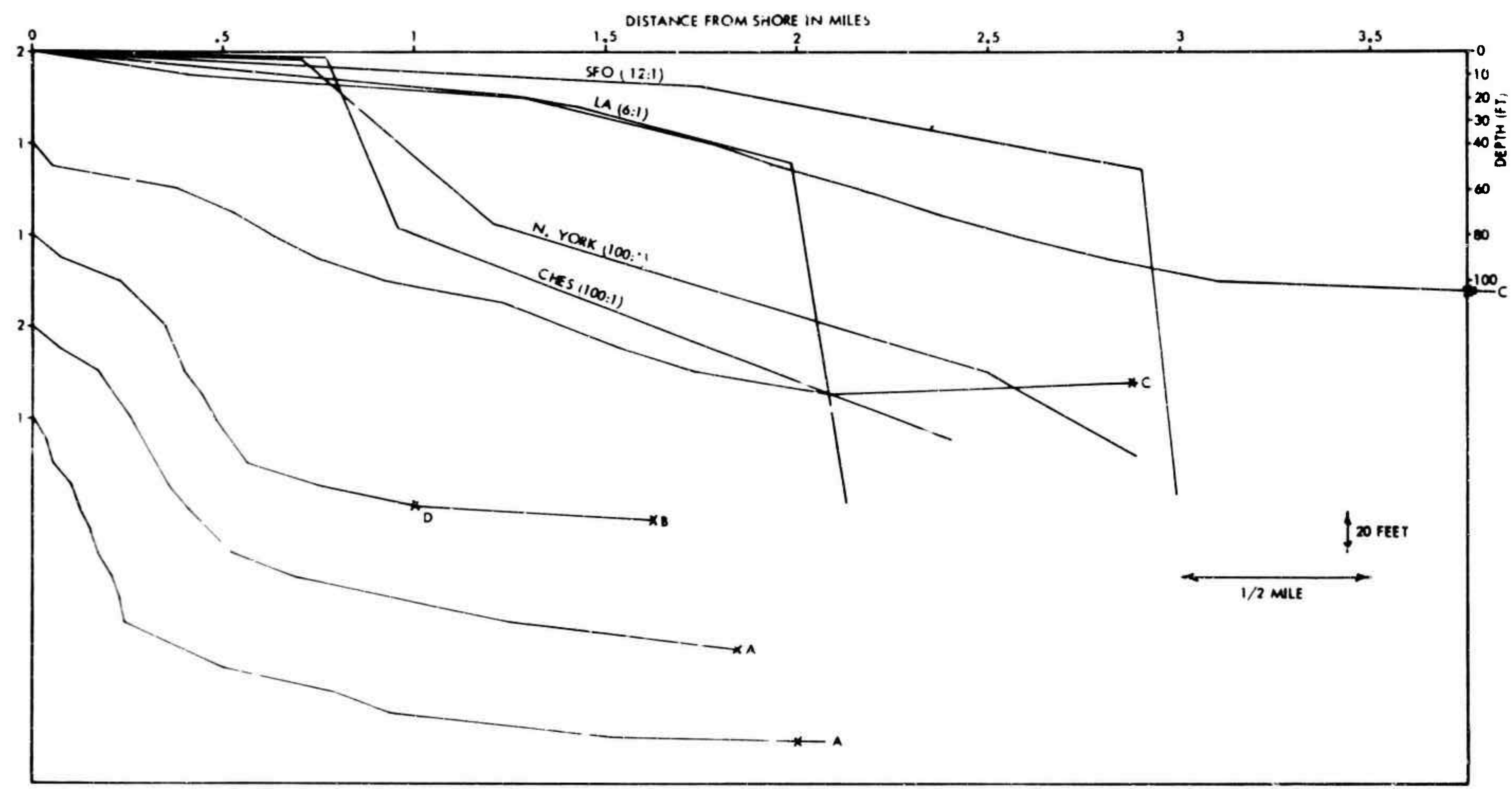


Figure 4. Bottom Profiles: Mono Lake, Pacific, Atlantic

It is to be emphasized that a serious constraint on scheduling of the proposed project at Mono Lake is weather. It appears that the program should be completed by mid-October or sooner, because storm conditions can render the area impossible for extended periods by late October or early November.

Details on instrumentation systems, charge fabrication and support systems, and the entire complex of the range operation are provided in the following pages, as is more information on the environment of Mono Lake and the surrounding pertinent area.

II
PRESENTATION OF RESULTS

This section presents the results of the feasibility study for the Mono Lake wave runup experiment. It is divided into the following subsections:

A. Site Description

B. Background Instrumentation

C. Range Instrumentation

D. Range Operation

E. Cost Estimate

A. SITE DESCRIPTION

This section presents a general description of the Mono Lake area and specific information on the geophysics of the lake and adjacent shoreline. In addition to the information contained herein, background wind and wave studies will remain in progress until completion of the experiment. The site description is divided into the following:

1. General Description
2. Geophysics
   (a) Geology
   (b) Meteorology
   (c) Limnology

1. General Description

Mono Lake (Monache — Yokut Indian word for "fly people"), Mono County, California, as shown in figure 1, lies at the base of the eastern escarpment of the Sierra Nevada Range at an elevation of 6389.5 feet above mean sea level (July 1964). Lee Vining (1960 population: 350), the closest town to the proposed test site, overlooks the southwest edge of the lake at an elevation of 6730 feet. Lee Vining is approximately 110 air miles from Reno, Nevada, and 180 air miles from San Francisco. A small airfield is located about one mile east of the town. US Highway 395, one of the three major north-south roads in California, goes through Lee Vining along the western edge of the lake, over Conway Summit, and then north to Nevada. The Greyhound Bus Line services

Lee Vining, on request, with its Los Angeles-Reno run along US-395 twice a day in each direction. State Highway 120 (Tioga Pass Road) joins US-395 approximately one-half mile south of town, follows US-395 south for four and one-half miles, and then proceeds east along the south side of Mono Lake. Both 395 and 120 are two-lane hard-surface roads in this area; however, State 120 is not maintained during the winter months and extensive road widening in the Tioga Pass area was scheduled to begin in June, 1965, lasting throughout the summer and fall. Numerous unmarked jeep trails are found around the lake. A four-wheel drive vehicle is required along at least parts of all trails investigated.

Mono Lake itself is roughly elliptical in shape with a north-south axis of 9.5 miles and an east-west axis of 13.5 miles, covering an area of approximately 85 square miles. Two major islands are located in the lake. The larger of these, Paoha (Indian for "diminutive spirits, having long, wavy hair, that are sometimes seen in the vapor wreathes ascending from hot springs"), is approximately one by two miles. The other, Negit (Indian word for "blue-winged goose"), is roughly circular with a diameter of three quarters of a mile. Several smaller islands as well as numerous tufa pinnacles and towers exist in the shallower waters (less than 50 feet). The lake water, because of its extreme salinity (approximately twice that of sea water), is inhabited only by brine shrimp and the nymph of the brine fly (Ephydridae). Some green algae also grows in the lake, with large amounts accumulating along the eastern shoreline. Ducks, grebes, and geese are seasonal inhabitants of the lake. Paoha Island is a protected gull rookery, the gulls nesting there from April to October.

Located at the edge of the high desert and Sierra Nevada Range, in the Upper Sonoran Zone (Pinyon-juniper forest) the climate and vegetation varies along the lake shore. Sagebrush, tumbleweed, plainsgrass, and scattered trees are the main plants of the southern shoreline. Animals observed include (but are not limited to) mice, hares, deer, and coyotes, the latter having a fond liking for neoprene-coated wire. Wild goats and hares are found on Paoha Island, having been introduced by the early white settlers. Small numbers of cattle and sheep are pastured along the lake shore.

The eastern edge of the lake presently is fenced in, the enclosed area extending from about one mile west of Warm Springs to the Hawthorne Road.

The lake receives water from rainfall, streams, and springs. Measurements at the western end of the lake (Mono Inn) indicate an average rainfall to be about 13 inches per year. The rainfall is expected to be somewhat less at the eastern end. The major streams in the area were intercepted by the city of Los Angeles in 1940 and at present contribute no water to the lake. Mill Creek, which flows from Lundy Lake, is the main stream flowing into the lake. Some smaller intermittent streams do flow into the lake. Springs apparently contribute the major portion of replenishment water at the present time. They range from mineral to fresh water and have been observed (vicinity Cement in figure 3) to discharge several gallons of water a minute. Numerous hot springs and fumaroles are located on and offshore eastern Paoha Island.

2. Geophysics

(a) Geology. - Mono Lake lies within Mono Basin, a volcano-tectonic depression of Pliocene age caused by a subsidence along faults following the extrusion of magma from a deep chamber. The old lake (Lake Russell) may have covered up to 300 square miles during the Pleistocene, having maximum water depth of from 820 to 860 feet. South of the present lake are the Mono craters, a series of rhyolitic volcanic domes of late Pleistocene age. Large volumes of pumice and obsidian erupted from the domes, the pumice now forming the major constituent of the sand found along the shore of the lake. It has been estimated* that the large triangular block associated with the Basin has subsided about 18,000 ±5,000 feet and is overlain by older Cenozoic (late tertiary) deposits. Above these is a 2000-foot thick layer of poorly-consolidated Pleistocene and Recent sediments.

The two islands in the lake contrast each other. The larger, Paoha, is white while the smaller, Negit, is black in color. Paoha is largely covered by lacustral sediments except for the northern and eastern ends, which are of recent volcanic origin. Negit Island is also of recent volcanic origin as indicated by the absence of sedimentary deposits of any kind; however, calcareous tufa is found coating some of the volcanic rocks to a height of 30 to 50 feet above lake level.

The present (and older) lakeshore abounds with calcareous tufa towers and calcareous coated pumice, obsidian, and rhyolite. These apparently result from the deposition of tufa from sub-lacustral springs and deposits from the water itself.

(b) Meteorology. - Little historical meteorological data are available for the site area. Some temperature and precipitation measurements have been made at Mono Inn, located on the west side of the lake (38° 01' N, 119° 09' W), for 1944; and from November 1950 to present. In addition, a weather station was maintained at Rush Creek Ranch (37° 57' N, 119° 04' W) from April 1948 to October 1950. The available data are given in figures 5 through 7. Rush Creek Ranch Station (figure 5) is located about two miles from the western edge of the proposed site area; however, the short meteorological record makes it impossible to correlate these data with the longer Mono Inn record. At the Mono Inn, the average yearly temperature (exclusive of 1965) is 48.4°F (figure 6) with extreme observed temperatures (1950-present) of -4°F and 96°F. The average annual precipitation (exclusive of 1965) at Mono Inn, over the 14-year period, was 12.90 inches (figure 7) with a minimum of 5.92 (1953) and a maximum of 25.48 (1955). The relative humidity around the lake ranges from about 30 percent during the day, to 50 percent at night.

During the present study, wind speed and direction measurements have been made continuously since early October (except during equipment breakdown). In general, the winds blow from the

* Pakiser, L. C., Press F., and Kune, M. F., 1960 "Geophysical Investigation of Mono Basin, Calif." Bull. GSA, 71, pp. 415-448.

AVERAGE TEMPERATURE — RUSH CREEK RANCH

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	ANNUAL
1948	-	-	-	42.9	48.2	55.8	62.6	61.0	56.0	46.3	35.9	25.5	
1949	14.6	22.2	32.5	46.5	50.1	58.6	63.8	61.5	57.2	45.0	36.7	28.2	43.1
1950	M*	-	-	-	-	M*	66.0	-	55.7	M*	-	-	

M* - 1 to 9 days record missing

TOTAL PRECIPITATION — RUSH CREEK RANCH

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	ANNUAL
1948	-	-	-	.96	.59	.94	T	.00	1.14	.39	.12	2.72	
1949	1.58	.80	1.02	.07	.92	.02	.37	.11	.10	1.22	.79	.34	6.34
1950	-	-	-	-	-	-	.08	1.19	-	-	-	-	

Figure 5. Temperature and Precipitation Data, Rush Creek Ranch

AVERAGE TEMPERATURE MONO LAKE

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	ANNUAL
1944	27.6	27.6	33.0	40.7	50.8	54.4	65.2	66.3	60.8	51.9	-	-	
1950	-	-	-	-	-	-	-	-	-	54.2M*	45.0	39.1	
1951	33.2	35.6	40.1	46.8	53.1	61.0	69.4	66.4	63.2	49.1	40.0	29.7	49.0
1952	25.6	29.8	31.3	45.4	54.9	57.6	66.9	68.6	61.3	57.1	35.7	30.6	47.1
1953	36.2	35.7	40.1	44.2	45.2	57.4	69.6	66.2	63.2	50.5	42.7	34.3	48.5
1954	35.1	32.5	35.3	49.6	57.9	59.5	68.7	64.2	60.3	51.7	42.8	31.6	49.1
1955	25.0	30.0	37.8	40.8	49.8	60.2	65.9	69.5	60.8M*	52.4	39.8	35.9	47.4
1956	36.2	30.1	40.3M*	44.5	52.1	60.2	65.6	64.3	62.1	48.6	39.0	33.9	48.1
1957	24.2	34.8	41.6	44.8	49.9	63.0	67.9	67.0	61.3	47.2	37.8	34.5	47.8
1958	33.2	37.0	34.4	43.2	56.6	59.6	66.8	70.3	62.2	53.3	39.8	37.5	49.5
1959	34.8	31.1	42.1	50.0	50.5	63.8	71.0	67.3	58.1	51.8	41.0	33.4	49.6
1960	28.0	32.9	43.5	47.4	52.6	65.3M*	69.0	67.7	62.5	49.4	33.7	31.6	49.0
1961	33.5	37.3	39.5	46.4	50.7	65.0	69.9	65.8	57.6	49.4	38.4	31.0	48.7
1962	27.5	28.1	32.1	49.9	49.4	60.9	65.3	65.7	61.5	52.4	41.8	34.9	47.5
1963	30.7	40.6	36.9	39.5	53.4	56.4	65.6	65.7	61.8	53.1	39.6	33.0	48.0
1964	30.9	31.6	35.5	42.7	49.4	59.6	68.5	67.1	58.5	54.6	35.2	35.6	47.4
1965	30.7	34.3	37.1	42.5	47.6	55.6	-	-	-	-	-	-	
Average	30.8	33.1	37.9	45.4	51.8	60.3	67.7	66.8	61.0	51.7	39.8	33.8	48.4

M* - 1 to 9 days' record missing

Figure 6. Average Temperature Data, Mono Inn

TOTAL PRECIPITATION MONO LAKE

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	ANNUAL
1944	1.62	3.13	1.36	0.33	0.42	0.76	0.01	0.00	0.07	0.22	2.86	2.00*	12.78*
1950	-	-	-	-	-	-	-	-	-	-	8.15	4.60	-
1951	0.71	0.43	0.08	1.61	0.29	0.72	0.58	0.36	0.50	0.52	2.32	4.88	13.00
1952	3.48	0.55	2.86	0.74	0.00	0.06	1.26	0.02	0.47	0.00	0.91	1.71	12.06
1953	1.17	T	0.43	1.09	0.94	0.43	0.19	0.17	0.30	0.63	0.38	0.19	5.92
1954	2.52	2.50	2.12	0.06	0.00	0.15	0.13	T	0.00	0.00	2.15	1.12	10.75
1955	1.03	0.70	0.26	0.39	1.04	T	2.82	0.31	1.07	0.00	1.20	16.66	25.48
1956	1.70	0.23	T	1.57	1.44	0.10	0.52	0.09	0.36	1.47	0.01	0.26	7.75
1957	2.53	2.80	0.14	1.70	2.12	0.00	0.16	0.03	0.15	1.17	0.59	1.79	13.18
1958	1.33	4.02	3.40	1.64	0.38	0.41	0.63	0.54	0.41	0.35	0.31	0.49	13.91
1959	1.45	4.42	0.16	0.18	0.74	0.01	0.01	T	2.81	T	0.00	0.25	10.03
1960	1.51	2.92	1.61	0.02	0.28	0.13	0.28	0.00	0.33	0.33	3.53	1.38	12.32
1961	0.22	0.35	0.59	0.55	1.50	0.26	0.21	4.55	0.29	0.12	1.20	0.66	10.50
1962	1.25	6.58	1.24	0.11	1.02	0.39	0.34	0.02	0.86	0.72	0.23	0.16	12.92
1963	8.38	2.97	1.96	1.34	1.48	1.21	T	0.17	1.10	0.67	2.34	0.35	21.96
1964	1.17	0.01	0.85	0.69	1.02	0.02	0.36	0.11	0.00	0.36	1.49	4.86	10.94
1965	5.59	0.49	0.90	0.37	0.34	0.73							
Average	2.23	2.01	1.12	0.80	0.84	0.31	0.50	0.42	0.58	0.44	1.73	2.58	12.90

* Estimated

Figure 7. Total Precipitation Data, Mono Inn

north-east during most of the year, with strong southerly winds developing during the winter months. Because of the scale limitations of the instruments, the maximum gusting speed (and sustained, in some cases) is not known, but is estimated to be about 70 to 80 mph. Figures 8 through 13 present the tabulated monthly data for the surface winds recorded at the instrument site. For presentation, the data have been divided into six months, from October 1964 to March 1965. Additional monthly data will appear as a supplement to the report.

From the figures, it can be seen that winds greater than 25 miles per hour rarely occur. During the six reported months, zero wind (both with and without occasional gusting) occurred approximately 70 percent of the recorded period. Those winds which were recorded during this period were predominantely from the southern quadrant with the remaining winds from the northern quadrant. Figure 14 presents the six-month summary of surface wind data at Mono Lake.

(c) Limnology. -

(1) Bathymetry. - During July, 1964, a bathymetric survey was conducted by personnel from Naval Ordnance Test Station, China Lake. At that time, the mean lake level was 6389.5 feet above mean sea level. Figure 2 shows the preliminary bathymetric contours and track lines run during the survey, while figure 3 shows the revised lake bottom contours.

Total Observations: 253								Sample Size: 34%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	145/57.1
0 (w/gusts)	-	-	-	-	-	-	-	-	40/15.7
1 - 5	-	2/.8	1/.4	-	3/1.1	8/3.1	6/2.4	1/.4	13/5.1
6 - 10	-	-	-	-	3/1.1	3/1.1	2/.8	-	10/3.9
11 - 25	-	-	-	-	1/.4	5/2.0	5/2.0	-	5/2.0
26 - 50	-	-	-	-	-	-	-	-	-
50 +	-	-	-	-	-	-	-	-	-
Total	-	2/.8	1/.4	-	7/2.6	16/6.2	13/5.2	1/.4	213/83.8

Figure 8. Surface Winds at Mono Lake - October 1964

Total Observations: 228									Sample Size: 32%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	46/20.0
0 (w/gusts)	-	-	-	-	-	-	-	-	44/19.3
1 - 5	-	12/5.3	5/2.2	-	9/3.9	11/4.8	12/5.3	3/1.3	-
6 - 10	-	6/2.6	4/1.8	-	3/1.3	10/4.4	6/2.6	-	-
11 - 25	-	8/3.5	2/.9	-	4/1.8	24/10.5	7/3.1	-	-
26 - 50	-	3/1.3	-	-	1/.4	8/3.5	-	-	-
50 +	-	-	-	-	-	-	-	-	-
Total	-	29/12.7	11/4.9	-	17/7.4	53/23.2	25/11.0	3/1.3	90/39.3

Figure 9. Surface Winds at Mono Lake - November 1964

Total Observations: 410									Sample Size: 55%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	166/40.4
0 (w/gusts)	-	-	-	-	-	-	-	-	54/13.1
1 - 5	-	-	-	1/.2	12/2.9	3/.7	1/.2	-	61/14.8
6 - 10	-	-	2/.5	-	5/1.2	5/1.2	1/.2	-	38/9.2
11 - 25	-	-	-	1/.2	1/.2	8/1.9	2/.5	-	32/7.8
26 - 50	-	-	-	-	3/.7	6/1.4	-	-	8/1.9
50 +	-	-	-	-	-	-	-	-	-
Total	-	-	2/.5	2/.4	21/5.0	22/5.2	4/.9	-	359/87.2

Figure 10. Surface Winds at Mono Lake - December 1964

Total Observations: 217									Sample Size: 29%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	156/71.9
0 (w/gusts)	-	-	-	-	-	-	-	-	17/7.8
1 - 5	-	-	-	-	-	-	-	-	14/6.4
6 - 10	-	-	-	-	-	-	-	-	7/3.2
11 - 25	-	1/.5	-	-	-	-	-	-	14/6.4
26 - 50	-	-	-	-	-	-	-	-	7/3.2
50 +	-	-	-	-	-	-	-	-	1/.5
Total	-	1/.5	-	-	-	-	-	-	216/99.4

Figure 11. Surface Winds at Mono Lake - January 1965

Total Observations: 588									Sample Size: 87%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	391/66.5
0 (w/gusts)	-	-	-	-	-	-	-	-	66/11.2
1 - 5	-	12/2.0	21/3.6	6/1.0	5/.8	6/1.0	7/1.2	4/.7	-
6 - 10	-	9/1.5	6/1.0	1/.2	5/.8	7/1.2	5/.8	1/.2	-
11 - 25	-	6/1.0	1/.2	-	3/.5	15/2.6	2/.3	-	-
26 - 50	-	-	1/.2	2/.3	4/.7	1/.2	1/.2	-	-
50 +	-	-	-	-	-	-	-	-	-
Total	-	27/4.6	29/4.9	9/1.5	17/2.9	29/4.9	15/2.6	5/.8	457/77.7

Figure 12. Surface Winds at Mono Lake - February 1965

Total Observations: 692									Sample Size: 93%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	393/56.8
0 (w/gusts)	-	-	-	-	-	-	-	-	140/20.2
1 - 5	-	13/1.9	8/1.2	9/1.3	7/1.0	13/1.9	21/3.0	4/.6	2/.3
6 - 10	1/.1	7/1.0	-	2/.3	8/1.2	8/1.2	11/1.6	4/.6	-
11 - 25	-	2/.3	1/.1	3/.4	8/1.2	12/1.7	10/1.4	3/.4	-
26 - 50	-	-	1/.1	-	-	1/.1	-	-	-
50 +	-	-	-	-	-	-	-	-	-
Total	1/.1	22/3.2	10/1.4	14/2.0	23/3.3	34/4.9	42/6.1	11/1.6	535/77.3

Figure 13. Surface Winds at Mono Lake - March 1965

Total Observations: 2,388				SUMMARY					Sample Size: 55%
Number of Observations/Percent Occurence for Direction and Speed									
Direction / Speed (mph)	NE	N	NW	W	SW	S	SE	E	No Dir.
0 (no gusts)	-	-	-	-	-	-	-	-	1297/54.3
0 (w/gusts)	-	-	-	-	-	-	-	-	361/15.1
1 - 5	-	39/1.6	35/1.5	16/.7	36/1.5	41/1.7	47/2.0	12/.5	90/3.8
6 - 10	1/0.4	22/.9	12/.5	3/.1	24/1.0	33/1.4	25/1.0	5/.2	55/2.3
11 - 25	-	17/.7	4/.2	4/.2	17/.7	64/2.7	26/1.1	3/.1	51/2.1
26 - 50	-	3/.1	2/.1	2/.1	8/.3	16/.7	1/.04	-	15/.6
50 +	-	-	-	-	-	-	-	-	1/.04
Total	1/.04	81/3.4	53/2.2	25/1.0	85/3.6	154/6.4	99/4.1	20/.8	1870/78.3

Figure 14. Summary of Surface Winds at Mono Lake - October 1964 through March 1965

The average lake depth is between 70 and 80 feet with a maximum recorded depth of 169 feet on the east side of Paoha Island. Figure 4 shows the bottom profiles along transits (figure 3) A-1, A-2, B-1, C-1 and C-2. A few typical slopes (scaled) off the Pacific and Atlantic coasts also are shown for comparison. As can be seen, the slope profile in the proposed test area (A-2) is steeper than the scaled Atlantic or Pacific areas. This implies construction of a less steep beach slope at the lake site.

(2) Chemistry. - Mono Lake, the third largest body of water wholly in California, is highly saline, containing 69,597 ppm of dissolved solids (figure 15). Previous analyses (in 1888) indicated a slightly different composition of the lake water; however, it is not known if the differences are the result of sample location, change in lake water composition, or analysis differences. Some deposition of calcareous tufa may be taking place at present in the tufa structures immediately east of Cement; however, enough observations have not been made to resolve this. No other active depositional areas have been noted.

Constituents	ppm
Ca	0
Mg	44
Na	25067
K	2444
CO_3	12300
HCO_3	5361
SO_4	8694
Cl	15317
NO_3	17
F	33
B	295
Si	25
Total Solids	69597

Location: North Shore of Mono Lake approximately Section 33, T3N, R, 27E.

Collected: 1145, June 23, 1960

Analyzed: July 13, 1960, by Division of Water Resources, State of California

Figure 15. Surface Water Analysis, Mono Lake

(3) Temperature. - To date, only one comprehensive water temperature measurement has been made; this was taken in the vicinity of the site on January 26, 1965. It showed a near-surface, near-shore temperature of $42^{O}F$. At the time of the measurement, the air temperature was $35^{O}F$. Additional observations show the surface water may freeze to a depth of 1/4 inch in some areas. This is presumably due to incoming fresh water and periods of extended calm which do not enhance vertical mixing, thus allowing a thin fresh water layer to lie above the denser lake water. Summer water temperature previously has been recorded in the $68^{O}F$ to $72^{O}F$ range. Many of the hot springs are in excess of $100^{O}F$.

(4) Currents. - One complete series of current measurements has been made both at 3-foot and 10-foot depths. These consisted of measurements between Paoha and Negit Islands, and a line of measurements between Paoha and the present instrument site. The shallower currents (3-foot depth) are no greater than 0.1 knot in all areas; however, at the 10-foot depth between the two islands, the current was found to be 0.2 knot. The directions measured indicated a clockwise circulation about Paoha Island, however additional measurements would be required to determine any long term changes in either magnitude or direction.

The longshore currents noted in the site area, always observed running toward the west, are sufficiently strong to transport sand and build up deposits along obstacles such as beached boats. On the downcoast (west) side of a beached boat, some erosion has been observed, with the shoreline re-establishing itself within a period of about 24 hours. Figures 16 and 17 show the shoreline before and after a boat has been beached for a period of about 24 hours.

(5) Sediments and Shoreline. - In general, the lake bottom is composed of silt and mud, except south of Paoha Island where old lacustral clays are found, and at various locations along the southern and eastern shore where pumice sand extends from the backshore to about the 5-foot contour. Apparently this sand has been wind-blown from the large pumice deposits to the south and keeps extending the sandy area toward deeper water. In the vicinity of the site, the sediments grade from a volcanic sand along the beach, to a firm ripple-marked sand in shallow water (less than five feet), to a sandy mud with occasional large pieces of pumice and hard clay lenses less than one inch in thickness (at 15 feet), to a poorly compacted mud or silt in the deeper water. The sandy mud and silt in this shallower water (less than 30 feet) is no thicker than six to twelve inches and appears to overlie a hard pumice bottom. The mud may be considerably thicker in other locations along the lake. Two such areas; the Mono Marina has mud up to two feet thick and the east side of Paoha Island has a mud thickness in excess of 15 feet.

Immediately west of the site area there is a large concentration of tufa structures. This type of structure also occurs throughout the test area in localized groups. Beyond Cement, the combination of tufa structures, swampy backshore, and muddy lakeshore makes the area unsuitable for experimental usage.

At the east end of the lake, where the bottom has a more desirable slope, the shoreline is soft, making it difficult to use unless extensive modifications are made. In addition, there is a swampy area along the backshore, which makes access to the lakeshore extremely difficult - except from the lake. Figure 18 (in the back-cover pocket) shows the bottom and shoreline sediments that have been observed along the shoreline.

(6) Waves. - During the present study, wave height measurements have been made since early October. The waves are generated by the local winds over a maximum fetch of about 10 miles and persist only a short time after the winds die down. Wave data were recorded for a five-minute period each hour. In general, there were no waves on the lake for approximately 52 percent

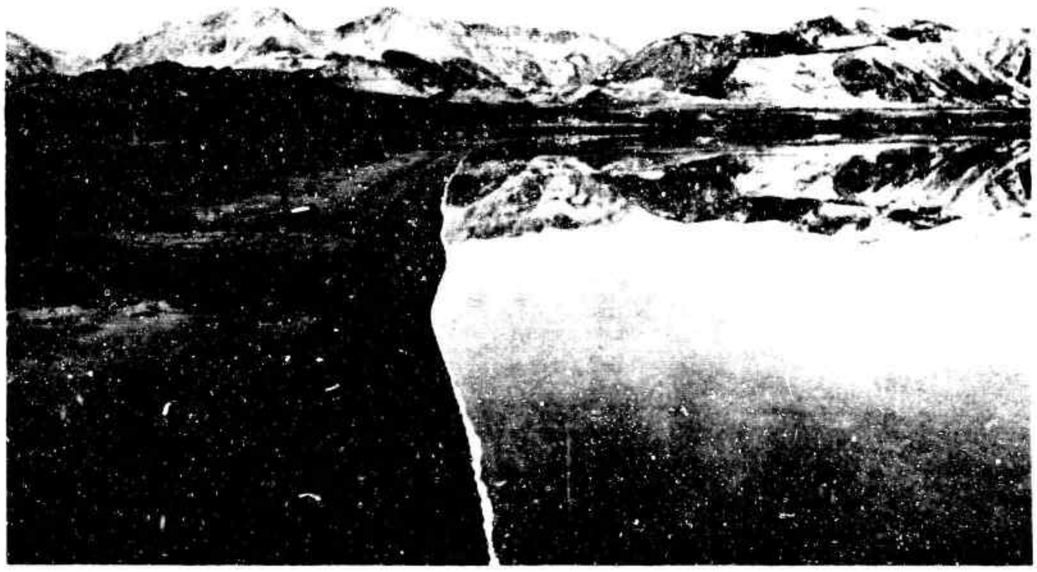


Figure 16. Shoreline (looking west) Prior to Beaching of Boat

Figure 17. Shoreline (looking west) After Boat Has Been Beached for 24 Hours

of the recorded time, with all waves being less than 1 foot in height for about 90 percent of the recorded time. Only 1 to 2 percent of the waves have periods greater than 3 seconds, with 88 percent of the wave periods being less than 2 seconds. Figures 19 through 24 present the tabulated monthly data for the surface water waves recorded at the instrument site. For presentation, the monthly data have been divided by maximum waves recorded in the 5-minute interval and average period. Figure 25 presents the 4-month summary of surface wave data at Mono Lake. It was observed that the incidence of morning calm was greater than the incidence of afternoon calm, during the length of record.

(7) Basin Oscillation and Water Level Changes. - Water level changes have been measured during historical times; the maximum fluctuations being as much as 17 feet. Apparently, such changes vary with the rain, snowfall and runoff. In 1940, all the large streams in the area (except Mill Creek which enters from Lundy Canyon) were diverted into the Los Angeles aquaduct system. In the 19-year period following (1940-1959), a 16-foot drop in the water level was recorded. During the present study, a lake level change of 6 to 9 inches has been observed with a resulting horizontal shoreline fluctuation of up to 20 feet in the site area.

The problem of basin oscillation has been examined. Additional instrumentation — in the form of a bottom-mounted pressure transducer — was installed to determine the presence or absence of these oscillations. No short-term (minutes) pressure changes exceeding 0.5 inch and no long-term (hours) changes exceeding 1 inch were observed.

Total Observations: 455				Sample Size: 617	
Number of Observations/Percent Occurence for Period and Maximum Height					
H_{max} (ft) \ Period (sec)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥3.0	Total
≤ Ripple	328/72.1	-	-	-	328 72.1
.1 to 0.9	-	103/22.6	11/2.4	-	114 25.0
1.0 to 1.9	-	3/.7	8/1.8	-	11 2.5
2.0 to 2.9	-	-	2/.4	-	2 .4
≥ 3.0	-	-	-	-	-
Total	328/72.1	106/23.3	21/4.6	-	-

Figure 19. Waves at Mono Lake - October 1964

Total Observations: 344					Sample Size: 48%
Number of Observations/Percent Occurence for Period and Maximum Height					
Period (sec) / H_{max} (ft)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥ 3.0	Total
≤ Ripple	134/39.0	-	-	-	134/39.0
.1 to 0.9	1/.3	140/40.7	29/8.4	1/.3	171/49.7
1.0 to 1.9	-	1/.3	37/10.8	1/.3	39/11.4
2.0 to 2.9	-	-	-	-	-
≥ 3.0	-	-	-	-	-
Total	135/39.3	141/41.0	66/19.2	2/.6	-

Figure 20. Waves at Mono Lake - November 1964

Total Observations: 402					Sample Size: 54%
Number of Observations/Percent Occurence for Period and Maximum Height					
Period (sec) / H_{max} (ft)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥ 3.0	Total
≤ Ripple	166/41.3	-	-	-	166/41.3
.1 to 0.9	-	133/33.1	53/13.2	10/2.5	196/48.8
1.0 to 1.9	-	12/3.0	22/5.5	3/.7	37/9.2
2.0 to 2.9	-	-	1/.2	2/.5	3/.7
≥ 3.0	-	-	-	-	-
Total	166/41.3	145/36.1	76/18.9	15/3.7	-

Figure 21. Waves at Mono Lake - December 1964

Total Observations: 423					Sample Size: 57%
Number of Observations/Percent Occurence for Period and Maximum Height					
Period (sec) / H_{max} (ft)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥ 3.0	Total
≤ Ripple	295/69.7	-	-	-	295/69.7
.1 to 0.9	-	96/22.7	14/3.3	1/.2	111/26.2
1.0 to 1.9	-	7/1.7	8/1.9	1/.2	16/3.8
2.0 to 2.9	-	-	-	1/.2	1/.2
≥ 3.0	-	-	-	-	-
Total	269/69.7	103/24.3	22/5.2	3/.7	-

Figure 22. Waves at Mono Lake - January 1965

Total Observations: 275					Sample Size: 41%
Number of Observations/Percent Occurence for Period and Maximum Height					
Period (sec) / H_{max} (ft)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥ 3.0	Total
≤ Ripple	144/52.4	-	-	-	144/52.4
.1 to 0.9	5/1.8	43/15.6	15/5.5	-	63/22.9
1.0 to 1.9	-	22/8.0	24/8.7	1/.4	47/17.1
2.0 to 2.9	-	2/.7	10/3.6	4/1.5	16/5.8
≥ 3.0	-	-	2/.7	3/1.1	5/1.8
Total	149/54.2	67/24.4	51/18.5	8/2.9	-

Figure 23. Waves at Mono Lake - February 1965

Total Observations: 516					Sample Size: 69%
Number of Observations/Percent Occurence for Period and Maximum Height					
Period (sec) / H_{max} (ft)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥ 3.0	Total
≤ Ripple	191/37.01	-	-	-	191/37.01
.1 to 0.9	64/12.4	179/34.6	16/3.1	-	259/50.1
1.0 to 1.9	-	49/9.4	10/1.9	4/.7	63/12.2
2.0 to 2.9	-	1/.1	2/.3	-	3/.5
≥ 3.0	-	-	-	-	-
Total	255/49.4	229/44.3	28/5.4	4/.7	-

Figure 24. Waves at Mono Lake - March 1965

Total Observations: 2415		SUMMARY			Sample Size: 55%
Number of Observations/Percent Occurence for Period and Maximum Height					
Period (sec) / H_{max} (ft)	0.0 to 0.9	1.0 to 1.9	2.0 to 2.9	≥ 3.0	Total
≤ Ripple	1258/52.0	-	-	-	1258/52.0
.1 to 0.9	70/2.8	694/28.7	138/5.7	12/.49	914/37.8
1.0 to 1.9	-	94/3.8	109/4.5	10/.41	213/8.8
2.0 to 2.9	-	3/.12	15/.62	7/.28	25/1.03
≥ 3.0	-	-	2/.082	3/.124	5/.207
Total	1328/54.9	791/32.7	264/10.9	32/1.3	-

Figure 25. Summary of Wave Data at Mono Lake - October 1964 through March 1965

(8) Runup. - An experiment was conducted to obtain a qualitative estimate of the runup energy loss due to friction and percolation. Sheets of plastic were placed along the beach slope extending into the water to depths of 2 to 3 feet. Large amplitude, long period waves were generated through the use of an outboard motor boat, and the resulting runup observed. No appreciable difference could be determined between the runup on the plastic sheeting and the runup on an adjacent uncovered segment of beach. It is felt that no modification for percolation and frictional effects is required; however, some slope modification may be desirable.

B. BACKGROUND INSTRUMENTATION

One of the main tasks of the feasibility study was the determination of background noise, with particular attention to the wind and wave regime. Accordingly, instrumentation was installed to take such measurements. Figure 26 presents the block diagram for the present background instrumentation.

1. Wind Speed and Direction

The wind speed sensor is a Science Associates Number 412 Wind Speed Indicator, and is a corrosion-proof, generator-type 10-inch diameter 3-cup rotor, whose output is an a-c voltage proportional to wind speed. The direction sensor is a Science Associates Number 413 Wind Direction Indicator, and is a chrome-plated potentiometer-type vane, allowing continuous readings for the full 360° rotation,

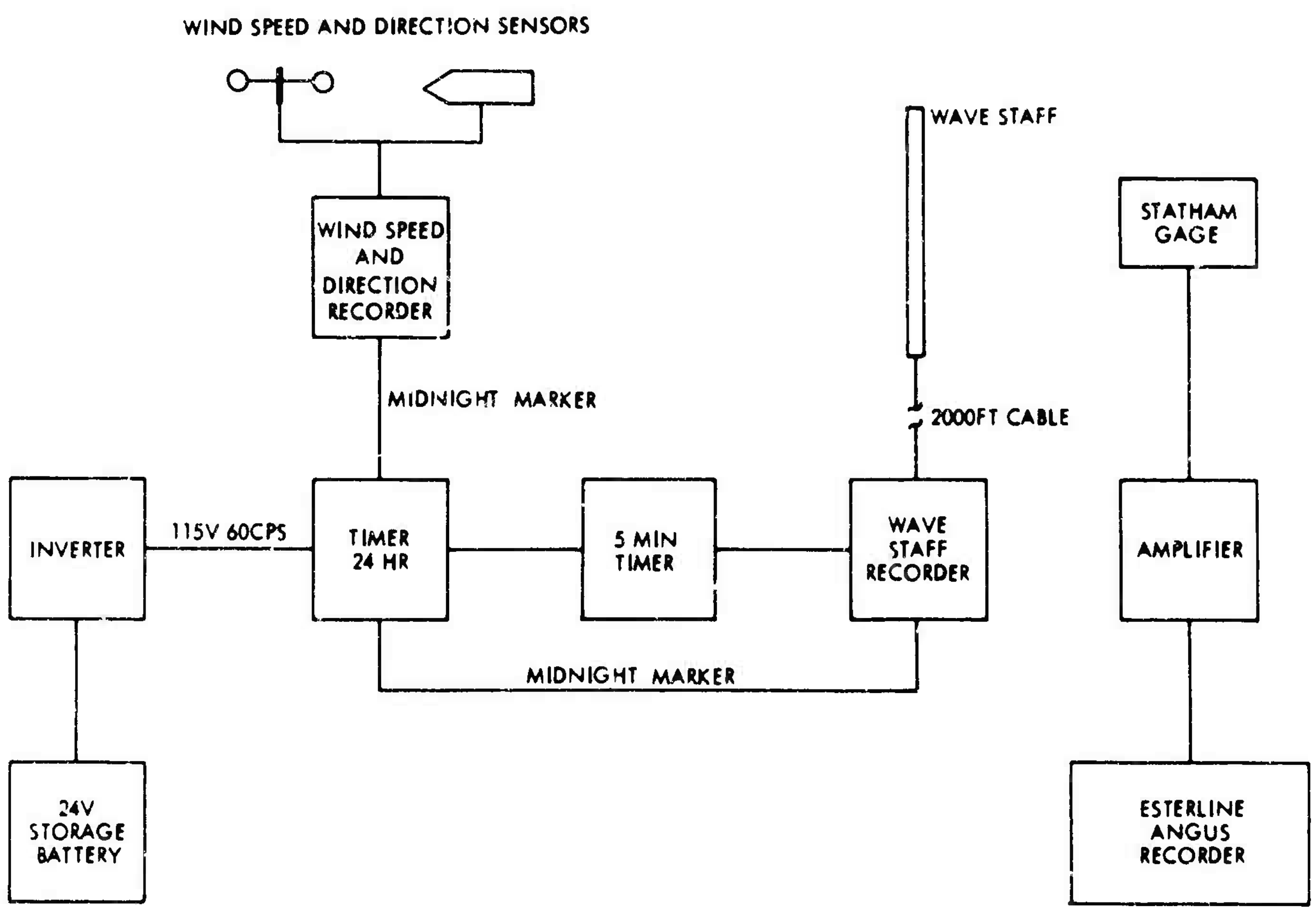


Figure 26. Background Wind and Wave Instrumentation, Block Diagram

and whose output is a variable d-c voltage. Both the wind speed and direction are recorded continuously on a Model 91 dual-channel 0-100 microamp d-c Rustrak recorder. The chart speed currently is set at 5 inches/hour, allowing a full-scale wind speed reading of 50 miles per hour.

2. Wave Height

The wave height (water level) sensor is a 10-foot National Marine Consultants Model SRS-1 resistance staff with linearity of ±1% over 90% of the dynamic range. The wave staff is mounted on a 30-foot guyed tower in approximately 25 feet of water. The staff is connected to a Moseley Model 17002A Autograf strip chart recorder by 2000 feet of cable. The recorder is programmed to allow a 5-minute recording each hour, with a chart speed of 2 inches/minute. Both the wind and wave records are marked at 2400 each day to allow time continuity over the recording periods. All equipment is run from a set of four storage batteries which supply 24 vdc for 4 days operation. The Rustrak operates directly from this 24-vdc supply. For timing and control, the 24 vdc is changed to 115 v 60 cps by a timing fork controlled inverter. This precise 60 cps operates a synchronous timer which initiates the hourly operation at the Moseley recorder, and provides the marker pulses at midnight.

3. Long Period Waves

An additional wave sensor was installed to allow detection of any seiche activity that might be present. This is a strain-gage bridge differential pressure transducer mounted 2 feet below the water surface. Both d-c power and signal are transmitted over a 4-wire cable to a spring-driven Esterline-Angus recorder. The chart speed is set at 3 inches/hour allowing continuous operation for approximately 8 days.

4. Field Operations

In general, the field operations were comparatively trouble free for the remote operational environment. However, some mechanical problems with the Rustrak recorder reduced the wind record time considerably (to 55% of the time). These included: (1) spool length problems which caused jamming of the paper during operation and (2) pen mount problems on one channel which caused loss of the direction data.

Other operational problems included excessive corrosion of the wave tower guying wires, which caused the wires to break and the tower to fall over. In 1 month, 5 of the 8 airplane cable guy wires broke. The tower presently is guyed with a heavier wire, and to date no problems have been encountered. Also, an unburied section of the cable was damaged by animals, putting the wave staff out of operation for a short time; however, almost complete burial of the cable solved that problem. The last problem encountered was the severing of the wave staff cable with a bulldozer during the road construction operations. The cable has been repaired and the instrument was returned to operation. Total operation time of the wave sensor was approximately 55 percent during the first 6 months.

C. RANGE INSTRUMENTATION

The following paragraphs describe the range instrumentation:

1. General Description
2. Sensor System
3. Buoy Telemetering System
4. Shore Based Telemetering and Command Station
5. Wave Measuring Systems
6. Photographic Coverage

1. General Description

All wave measurements are to be made with wave staffs. These are 1-inch diameter resistance probes which penetrate the surface. The active portion of each staff is 4 feet in length, with its midpoint located at nominal surface level.

At each measurement station, electronic conversion from wave height to frequency analog is made. The frequency data then are transmitted to a central recording site. The near-shore stations are connected to the recording site by hard wire. The deep water stations send their data via a radio-telemetry link.

Wave staffs in water of 20-foot depths or more are supported by taut-wire subsurface buoys. Those in shallower water, or on the beach, are supported by posts driven into the lake bottom.

The frequency analog signals from up to 60 wave staff stations are brought together at the central recording and instrumentation station, where all are recorded directly on analog magnetic tape.

Eight of the signals are recorded on strip chart for real-time evaluation. The instrumentation station also provides timing for the test operation. The timing has two principal elements:

(1) A firing sequence control, which allows the recorders and cameras to be started just prior to firing and also fixes the firing of the explosive charge in real (NBS) time.

(2) A timing system that places a time-of-firing mark and a series of elapsed time marks on all records (slow-motion film, strip chart, and magnetic tape).

A communications system provides radio links between the recording site, the firing control site, and the three Fastax (slow-motion) cameras. It also links all sites, vehicles, and, at Lee Vining, connects to commercial telephone service.

2. Sensor System

(a) Basic Transducer. - Wave height sensing is accomplished with a resistance staff constructed as shown in figure 27. The nominal resistance of the winding is 500 ohms in air. As the water level rises, a portion of the wire is shorted. Thus the total resistance varies inversely with water height. The spiral winding provides infinite resolution. The technique has been proven in service.

(b) Bridge Controlled Oscillator. - The resistance variations of the wave staff are converted to a frequency analog to allow wave data transmission by wire or radiotelemetry over distances of several miles. This conversion is made by a bridge controlled oscillator (BCO), an amplifier with a Wheatstone bridge in its feedback loop. As the resistance changes, it unbalances the bridge to varying degrees and thus changes the frequency of oscillation. The linearity of frequency to resistance is on the order of 0.1 percent. Because the wave staff is an element of the oscillator, it is excited at the frequency of oscillation (typically between 1 and 15 kc).

The BCO is used for the following reasons:

(1) It provides a-c excitation for the wave staff; d-c excitation cannot be used because of electrolysis and polarization effects caused by wire contact with conductive water.

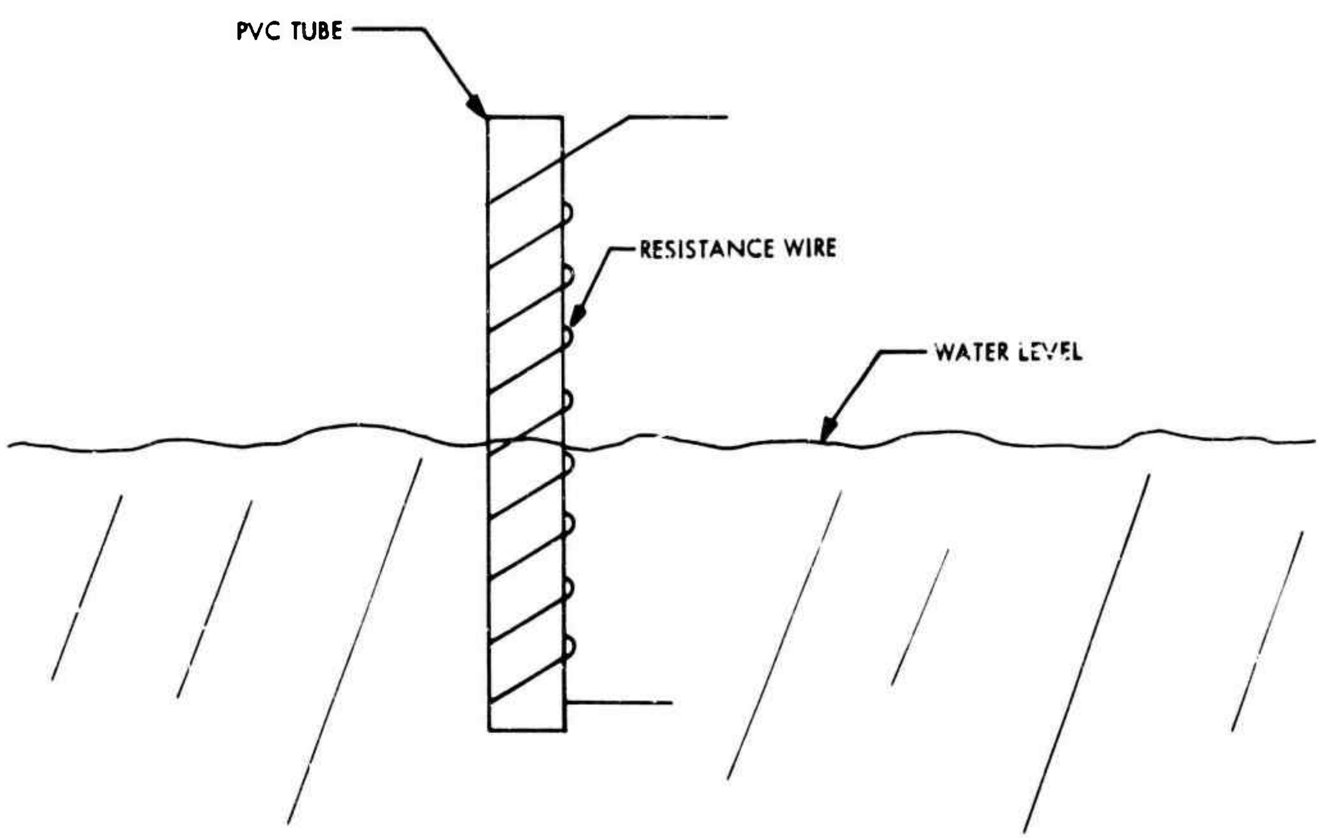


Figure 27. Wave Staff

(2) The frequency analog of wave height is produced in a minimum number of steps: this frequency analog can be transmitted long distances without degradation of data accuracy, while the staff resistance variations cannot.

(c) Sensor Deployment. - The sensor deployment described in this study is shown in figure 28. There are 45 "hard-wire telemetry" sensors near or on the shore, 9 radiotelemetry sensors in deep water, and 6 radiotelemetry sensors available for location as required for the tests.

Division of the sensors into hard-wire and radiotelemetry types is dictated by economic and operational considerations. The nine deep-water sensors lie at a distance from the recording trailer where the cost of wire exceeds the cost of the telemetry equipment. Also, the weight of the spools of wire at these lengths makes laying the wire from a small boat quite difficult and time consuming.

The six remaining radiotelemetry sensors are capable of being moved to various locations as the tests proceed. This would be extremely difficult to do if the sensors were of the hard-wire telemetry type.

(d) Hard-Wire Telemetry Sensors. - The electrical arrangement of these sensors is shown in figure 29. The wave staff, bridge, and BCO are located at the sensor station. A four-wire cable, connecting each sensor to a shore installation, transmits analog data to shore and d-c power to the BCO. Six different frequency bands (IRIG Bands 8 to 13) are used for the sensors (figure 30). These hard-wire sensors are grouped as shown in figure 28. Each array of six sensors is coupled to a mixer (figure 31). At this point, the signals are combined in an operational amplifier to allow transmission to the recording trailer over a single line. The mixer housing also contains batteries which provide d-c power to the sensors through individual constant current generators. The batteries are switched on and off by a controlled relay from the recording trailer.

As shown in figure 28, there are a total of eight mixers deployed along the beach as required by sensor placement.

(e) Radiotelemetry Sensors. - The basic sensors are as described above; however, the BCO frequencies are in IRIG channels 6 and 7 (figure 30). The BCO outputs are connected to radio-transmitters for transmission to the recording trailer. Each sensor operates entirely on self-contained batteries which are switched on and off by radio control from the recording trailer. This arrangement is described in detail in section C-3.

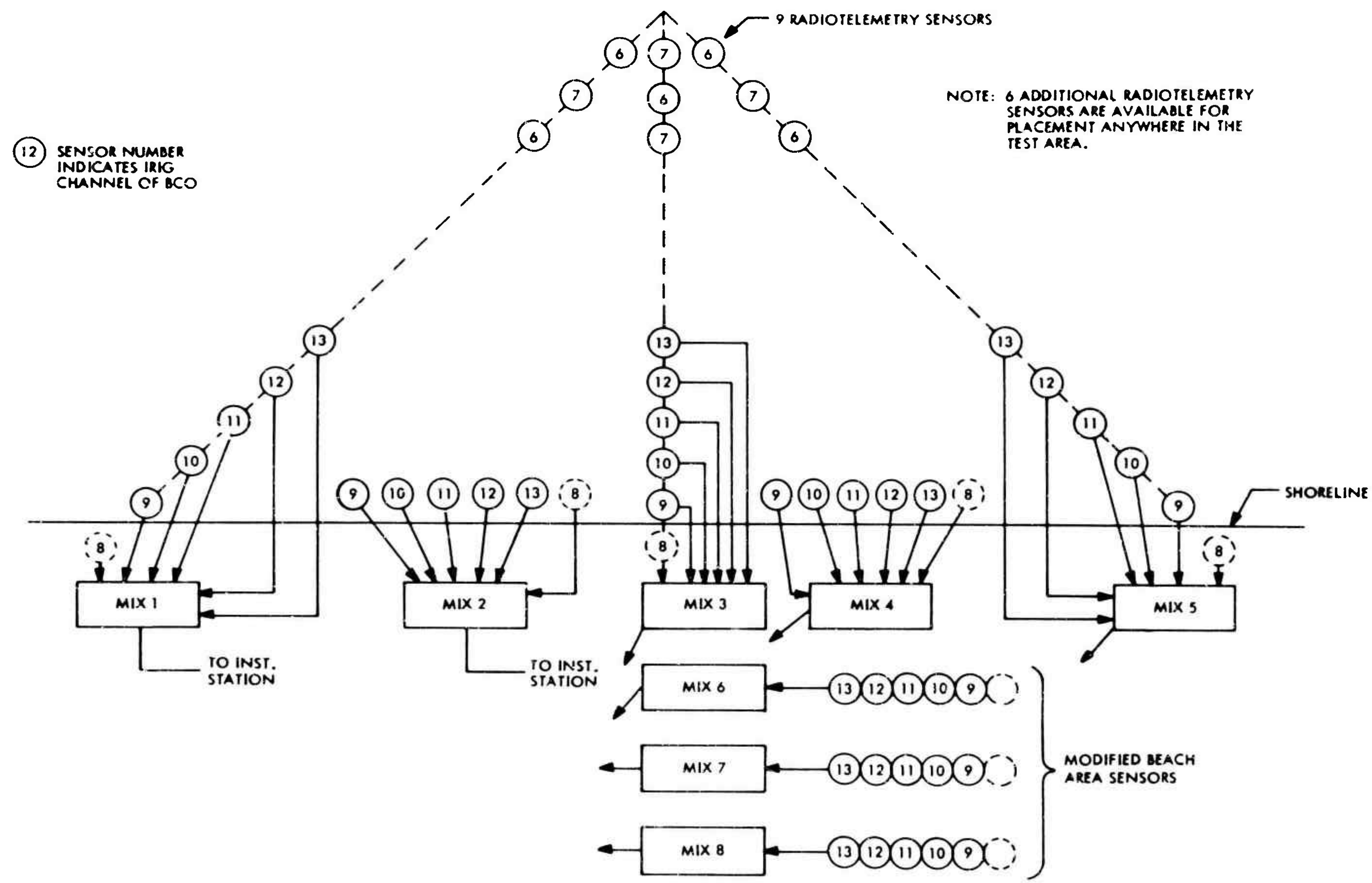


Figure 28. Sensor Deployment

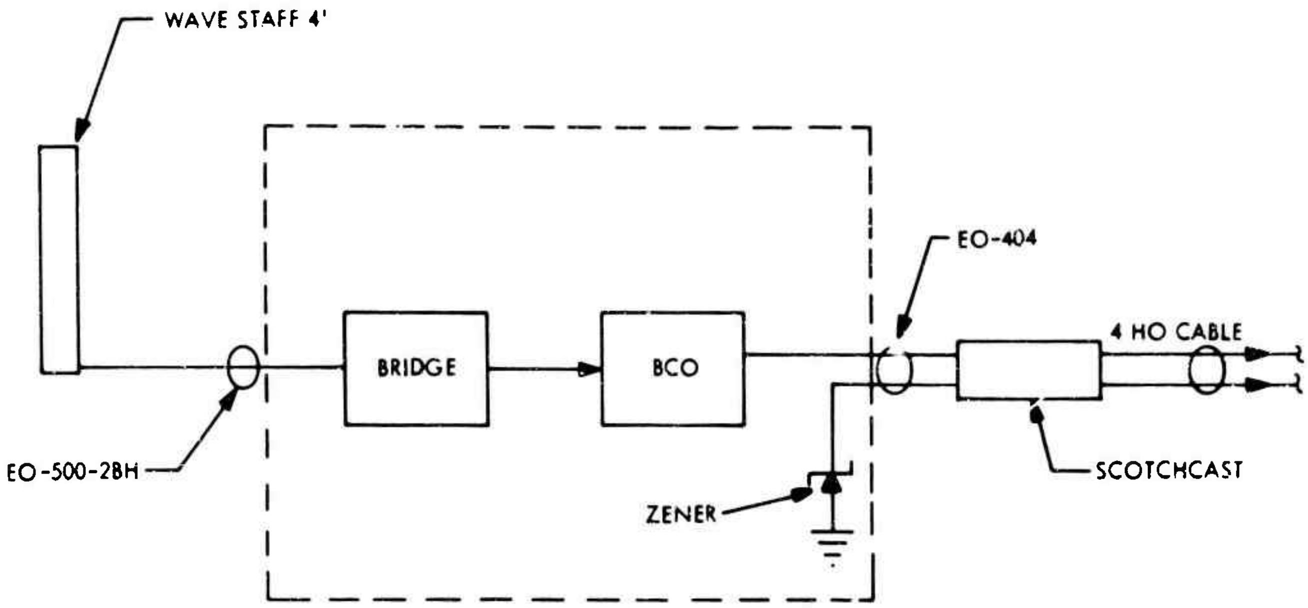


Figure 29. Hard-Wire Sensor Package, Electrical Diagram

IRIG BAND	FREQUENCY
6	1572 - 1828 cps
7	2127 - 2473
8	2775 - 3225
9	3607 - 4193
10	4995 - 5805
11	6799 - 7901
12	9712 - 11288
13	13412 - 15588

Figure 30. Frequency Bands Used for Instrumentation

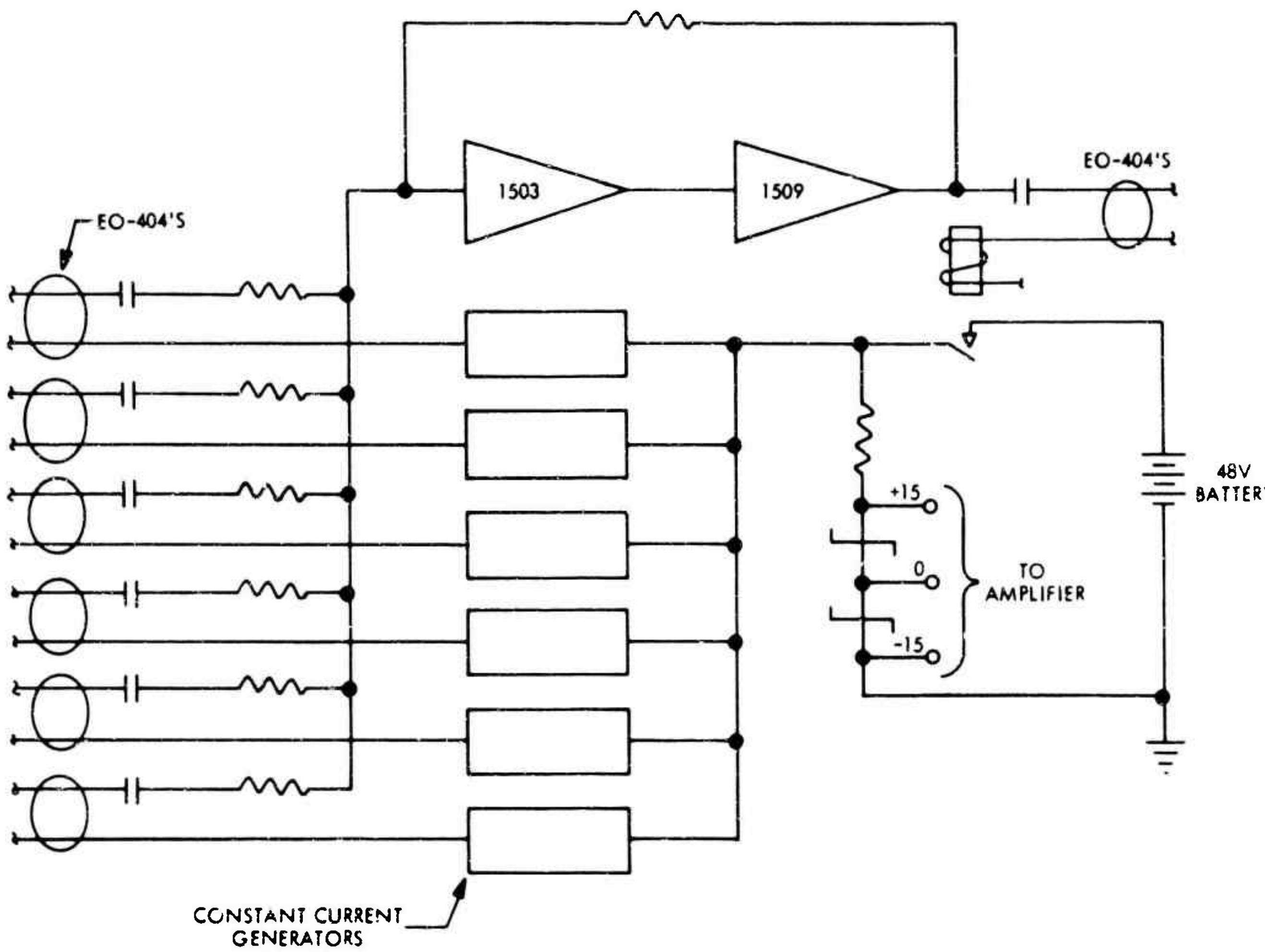


Figure 31. Hard-Wire Sensor Mixer

(f) Recording System. - The recording system is shown in simplified form in figure 32. The hard-wire telemetry signals from each shoreline mixer are combined with two of the radio-telemetry sensor signals, to form a "composite" of eight frequency-multiplexed sensor signals. A total of eight such "composite" signals are produced for recording on four 2-channel tape recorders In addition, any one composite can be recorded on an 8-channel strip chart recorder.

The advantages of this recording system are:

(1) Any group of eight sensors can be observed in real time on the strip chart recorder. This allows pretest checking of any sensor and monitoring of selected sensor outputs during tests.

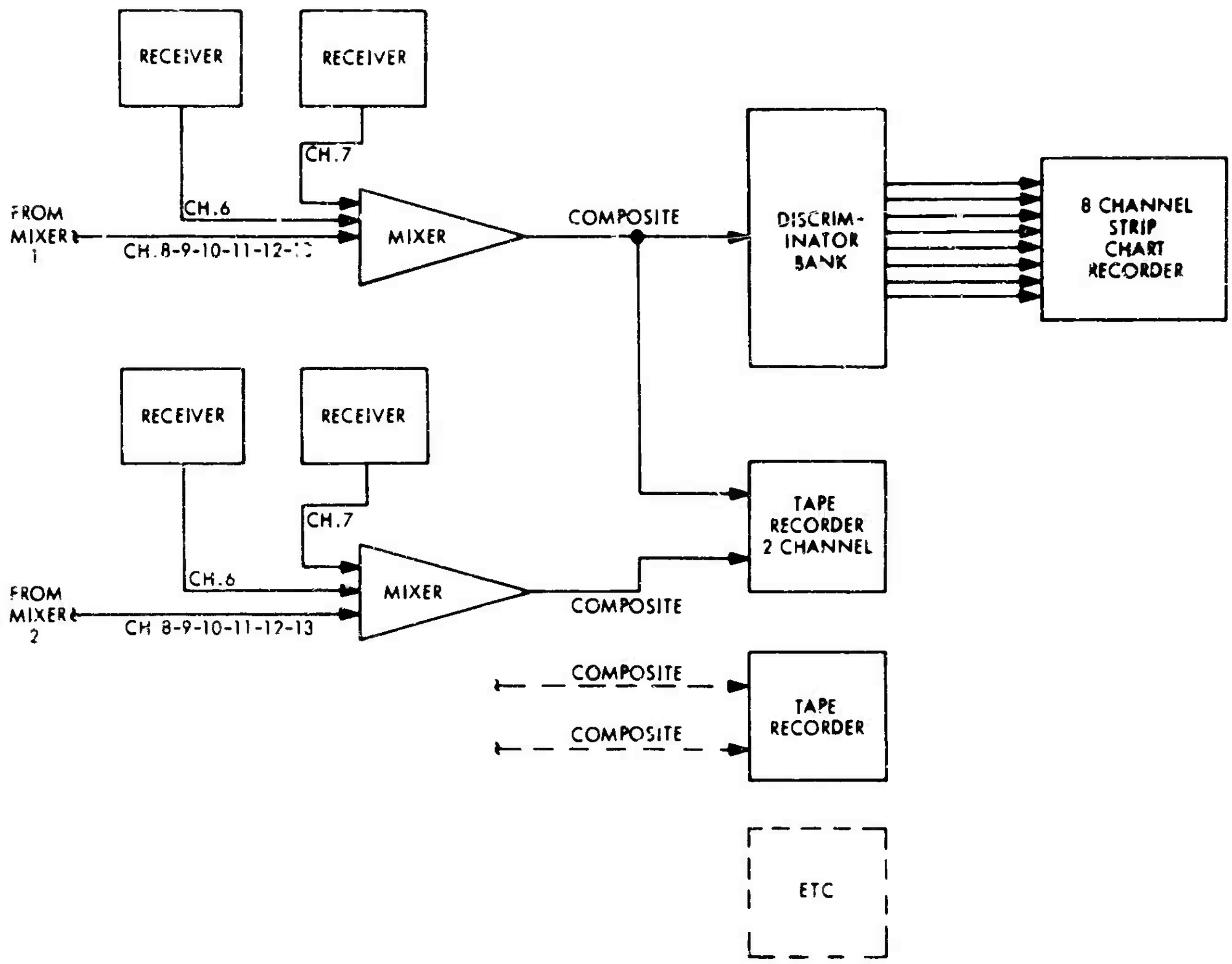


Figure 32. Recording System, Simplified Diagram

(2) Following a test, the tapes can be played back into the strip chart recorder so that all records are available for inspection shortly after the test is concluded.

(3) The magnetic tape records, which are compatible with IRIG standards, are available for playback into digital or analog equipment at any future time.

(g) Timing and Control System. -

(1) General. - The timing functions are shown on the complete block diagram of figure 33 (included in the back-cover pocket). Basic range timing is provided by an accurate tuning fork oscillator. For purposes not directly required by the test instrumentation, the fork is compared to WWV, allowing the firing time to be known in the real time domain. Recordings are made with reference to the firing time.

(2) Firing Sequence. - In reference to figure 33, the 60-cps fork signal is divided to produce one pulse per second, which is compared on an oscilloscope to the 1-pps WWV signals, and adjusted to synchronism. The synchronized 1-pps signals are further divided to one pulse per minute. A manual reset on the divide 60 counter allows synchronization of the 1-ppm pulses with WWV 1-ppm signals.

The sequence of events preceding firing is:

a) The instrument ready switch is closed shortly before firing time.

b) The "ARM" switch (on the island) is closed to initiate the programmed countdown and firing (if required, this sequence can be halted by opening the firing switch). The "ARM" signal is telemetered to the recording trailer, sensed by the "ARM" Control Decoder which readies the intervalometer.

c) On the next real time minute, the intervalometer starts. It indicates that the recorder should be started, gives camera start signals at the proper time and, on the next real time minute, issues the firing pulse.

d) The firing pulse is telemetered to the island, firing the squib. The same pulse is sent to the cameras and all recorders to indicate the firing time. This pulse is a burst of 100-cps carrier for the tape recorders, and a burst of 2575 cps for the fire command decoder on the island. A 100-cps detector produces a d-c pulse for the strip chart recorder.

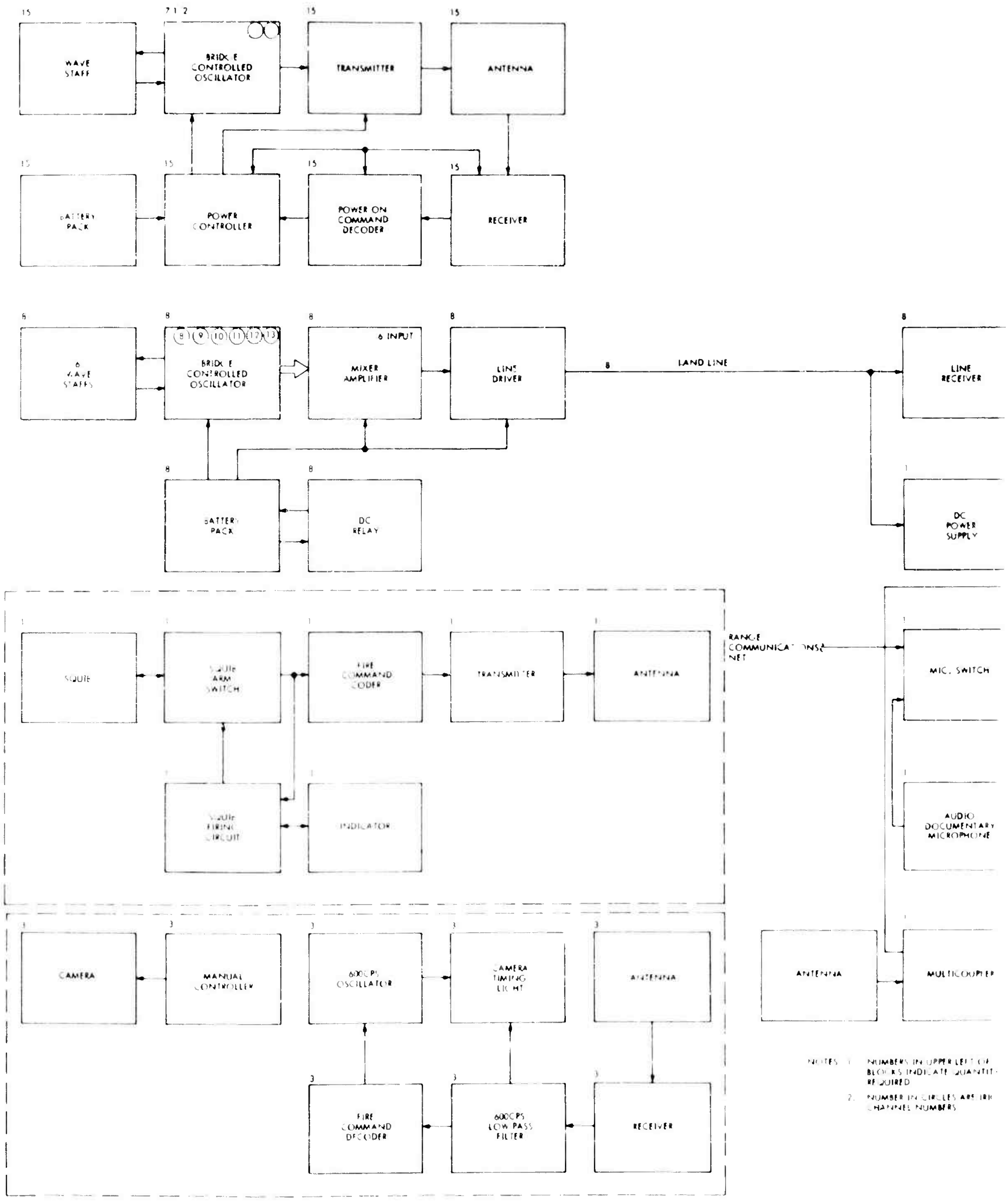
(3) Alternative Timing and Control System. - A simplified timing and control system is shown in figure 34. This alternative method provides only time-of-firing and elapsed time marks on the records.

Operation of the alternative system is as follows:

a) A countdown from the firing position over the range communications net allows operators of the recorders and cameras to turn on their equipment at the proper times.

b) A fire command signal at the time of firing is transmitted by a radio link to the recording trailer and to the camera stations. This impulse is recorded on tape, strip chart, and camera records.

c) Elapsed time marks at 60 cps (tape recorders) 600 cps (cameras) and 1 cps (strip chart) are provided.



15
WAVE STAFF
BRIDGE CONTROLLED OSCILLATOR
TRANSMITTER
ANTENNA
BATTERY PACK
POWER CONTROLLER
POWER ON COMMAND DECODER
RECEIVER
6
6 WAVE STAFFS
8
BRIDGE CONTROLLED OSCILLATOR
9
10
11
12
13
6 INPUT
MIXER AMPLIFIER
LINE DRIVER
LAND LINE
LINE RECEIVER
BATTERY PACK
DC RELAY
1
DC POWER SUPPLY
SQUIB
SQUIB ARM SWITCH
FIRE COMMAND CODER
TRANSMITTER
ANTENNA
SQUIB FIRING CIRCUIT
INDICATOR
RANGE COMMUNICATIONS NET
MIC. SWITCH
AUDIO DOCUMENTARY MICROPHONE
3
CAMERA
MANUAL CONTROLLER
600CPS OSCILLATOR
CAMERA TIMING LIGHT
ANTENNA
FIRE COMMAND DECODER
600CPS LOW PASS FILTER
RECEIVER
ANTENNA
MULTICOUPLER
NOTES: 1. NUMBERS IN UPPER LEFT OF BLOCKS INDICATE QUANTITY REQUIRED
2. NUMBER IN CIRCLES ARE IRIG CHANNEL NUMBERS

A

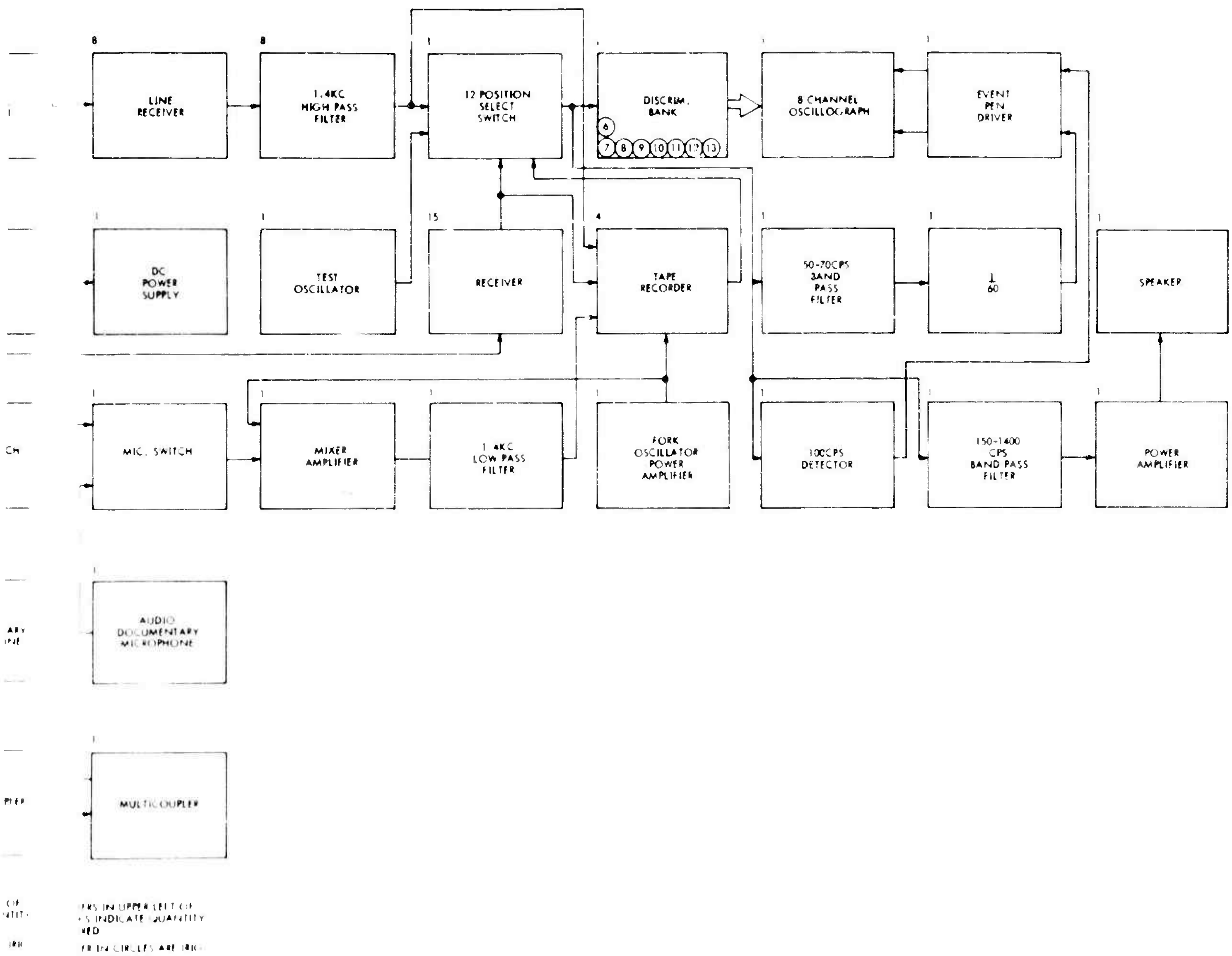


Figure 34. Simplified System Block Diagram

This system does not provide real time reference, although it still provides the desired system flexibility.

(h) Timing. - In addition to the time-of-firing pulse, precision elapsed-time timing is recorded. For the tape recorders this is a 60-cps sine wave, derived from the fork oscillator and recorded directly. For the strip chart, the 60 cps is divided to one pps which operates an event marker pen. The 60-cps signal is telemetered to the cameras.

(i) Documentation. - A voice channel is provided on the tape recorder for indentification of the tapes prior to each test.

3. Buoy Telemetering System

(a) Frequency Selection. - A telemetering system (figure 35) to cover a distance of less than seven miles will be required for the offshore sensors. The short range and ideal conditions suggest the use of a low-powered solid-state vhf transmitter. The data band of interest is very narrow, therefore a f-m transmitter with "voice" communication bandwidth is sufficient (300-3000 cps).

Two frequency bands have been set aside for Hydrological and Meteorological data transmission. One is in the vhf range from 169.425 mc through 171.925 mc. The other is in the uhf range from 406.025 mc through 412.775 mc. Either would provide reliable data transmission over the specified distance. Equipment availability at this time has dictated the vhf frequency range.

(b) Transmitters. - Motorola Communication and Electronics Company has both solid-state f-m transmitters and receivers (in the above-noted range) which may be obtained individually. The basic exciter operates from 14 vdc, has an output power of 1.4 watts, and an audio pass band of 300 to 3000 cycles. The Motorola Model NTD 6073AA 1.4-watt exciter has been used successfully in a similar application.

Specifications are as follows:

R-F Output:	1.4 watts/50 ohms
Frequency Stability:	0.0025%
Modulation:	16F3 ±5 kc for 100% @ 1000 cps
Crystal Multiplication:	18 times
Spurious and Harmonics:	-45 db below carrier
F-M Noise:	-50 db below ±3.3 kc deviation at 1000 cps
Audio Response:	+1, -3 db of 6 db/active pre-emphasis characteristics from 300 to 3000 cps
Primary Power:	14 vdc @ 0.250 amp

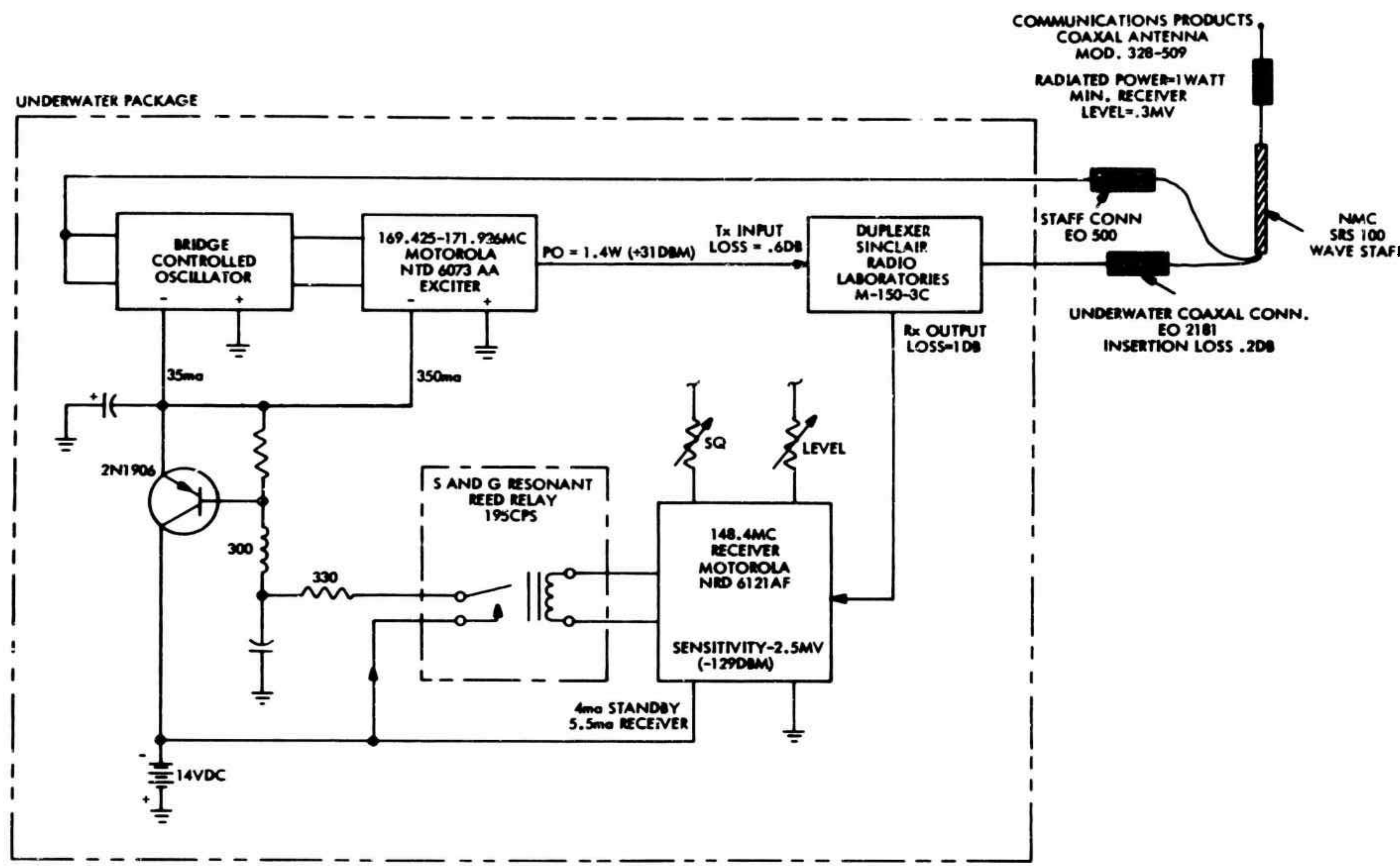


Figure 35. Buoy Telemetry System

In any data transmission system it is desirable to maintain a high signal to noise ratio. If the receiver at the recording station has a threshold sensitivity of 0.5 microvolt, a signal level of 40 db above threshold would provide the desired margin of safety (40 db above 0.5 microvolt is ≈ 30 microvolts). With a transmitter output of 1.4 watts, a system loss of 2 db (cable loss, etc.) and a unity gain antenna, the received signal would be:

Radiated Power:	1.4 Watts -2 db = 0.880 watts = 29.4 dbm
Path Loss:	7 mi. @ 170 mc = -99 db
Radiated Power:	+29.4 dbm
Path Loss:	-99.0 db
Received Signal:	-69.6 dbm
or	≈ 70 db below one milliwatt

With a receiver input impedance of 50 ohms, the received signal will be 70 microvolts or 50 db above the receiver threshold. If the operating frequency were 405 mc, the received level would be 8 db less or 27.8 microvolts/50 ohms.

(c) Receivers. - The control receiver should also be solid state and operate in the same frequency range as the transmitter if possible. It also must have low standby current requirements and be crystal controlled. The Motorola Model NRD 6121AF readily lends itself to this application and has also proven itself in previous applications. The specifications are as follows:

Modulation Acceptance:	±5 kc
Channel Spacing:	±30 kc
Sensitivity:	0.5 microvolt for 20-db quieting
Selectivity:	80 db at adjacent channel
Frequency Stability:	0.0025% from -30°C to +60°C
Spurious and Image Rejection:	over 60 db
Squelch Sensitivity:	0.25 microvolt
Primary Input Power:	14 vdc
Standby Current:	4 ma
Received Current:	55 ma

(d) Remote Control. - Considering the number and location of the buoys, it is advantageous to remotely control the power to the signal conditioning and transmitting equipment. A simple and very reliable method of remote controlling any device is through the use of a resonant reed relay. This is a frequency sensitive switch, which has as a natural characteristic, narrow bandwidth (±2 cps) and high selectivity. Normal frequency ranges of these units are between 80 cps and 800 cps. An additional advantage of the resonant reed relay is the signal-to-noise ratio. The signal voltage required to operate the device is two volts, while over 40 volts of noise is necessary to obtain a false output (26 db). In using the resonant reed relay, it must be understood that the

vibrating reed is the contact closure; therefore, the output is intermittent, occurring every half cycle. This intermittent closure then may be used to charge a capacitor, thus controlling an electronic switch. Typical resonant reed relay characteristics are:

Frequencies:	80 cps to 800 cps
Input Power:	7 milliwatts (2 vrms)
Bandwidth:	±2 cps nominal
Contact Rating:	12 vdc @ 100 ma, 48 vdc @ 10 ma
Contact Dwell Time:	10% typical @ 2 vrms input
Coil Characteristics:	DC Resistance 600 ohms ±10%
Response Time:	100 milliseconds
Sensitivity:	0.7 vrms
Size:	1.375 x 0.75 x 0.375
Manufacturer:	Sargent and Greenleaf, Inc.
Model No.:	M510

(e) Duplexer. - Considering the small size of the buoy, it is desirable to operate the transmitter and the command receiver from the same antenna. Actually, the problems of coupling to one antenna are less than using two antennas, unless the radiators are spaced several wavelengths apart ($\approx$ 15 feet at the frequency we are considering). If a reasonable frequency separation is maintained between the control receiver and the telemetering transmitter (5-mc minimum), a simple 3-section duplexer may be used. The duplexer consists of one tuned circuit at the transmitter frequency and two tuned circuits in the receiver input circuit acting as traps to the transmitter frequency. A device of this type is manufactured by the Sinclair Radio Laboratories, Tonawanda, New York. The electrical characteristics are as follows:

Frequency Range:	150 to 174 mc
Isolation Tx to Rx:	Greater than 55 db -70 db at resonance -55 db ±130 kc from resonance
Insertion Loss:	0.6 db transmit 1 db on receive
VSWR:	Less than 1.5 to 1
Power Rating:	50 watts
Impedance:	50 ohms
Model Number:	M-150-3C
Size:	2-3/8" x 4" x 5"
Weight:	38 oz.

(f) R-F Connector. - One problem encountered in the system design is that of making a reliable underwater r-f connection. Investigation of available connectors shows that the Electro-Oceanics Model 21B1M with the 21B1F meets the electrical requirements, and may be assembled under water. The connector impedance is 50 ohms; insertion loss is 0.2 db at 400 mc, and the VSWR is less than 1.3/1 from 0 to 400 mc. The connector is molded from neophrene rubber and is supplied with an attached length of coaxial cable. Normally the cable supplied is RG188/U, but RG58/U may be substituted.

(g) Operation. - Fifteen systems are required for the proposed operation; therefore, the telemetry transmitters carrier frequency will be in 150-kc increments, starting at 169.425 mc. All of the command receivers will operate at 148.4 mc with the command tone at 195 cps.

Normal operation of a buoy system is as follows: a 148.4-mc signal modulated with 195 cps is received by the antenna and fed to the receiver through the duplexer. The 195-cps audio tone then is amplified and applied to the resonant reed relay, which in turn controls a pass transistor, applying power to the bridge controlled oscillator and telemetering transmitter. The output of the telemetry transmitter then is fed to the antenna through the second input to the duplexer. As long as the receiver receives a tone modulated signal, the telemetry transmitter will remain on the air; when the control signal is turned off, the complete system shuts down except for standby receiver power, which will be about 60 milliwatts. For the over-all range system (figure 33), the telemetry command system is used to turn on remote cameras, transmit timing to these cameras (figure 36), and send the "FIRE" command to the Range Safety Officer. The fire control telemetry system (figure 37) is a duplicate of the buoy telemetry system (figure 35); however, L-C filters will be used in the timing and "FIRE" command systems, because of the required shorter response characteristics. An "ARM" command transmitter also is used in conjunction with the fire control system. Electrically, this transmitter will be the same as the buoy transmitter and will use a resonant reed relay to generate the "ARM" signal.

4. Shore Based Telemetering and Command Station

The shore based telemetering and command station (figure 38) must serve three functions:

(1) Receive and distribute 15 signals from the buoys to 15 receivers.

(2) Transmit command signals to the buoys and cameras, timing to the cameras, and fire command to the Range Safety Officer.

(3) Receive the "Arm" signal from the Range Safety Officer.

(a) Telemetry Receivers. - The telemetry receivers suggested for use are the same solid-state units used in the buoys (Motorola NRD 6121 AF). Additional equipment required to complete the telemetry system would be a power supply, an antenna, and a multicoupler. Because of the large number of outputs required, several simple multicouplers (such as the Motorola TLD 622A) could be used.

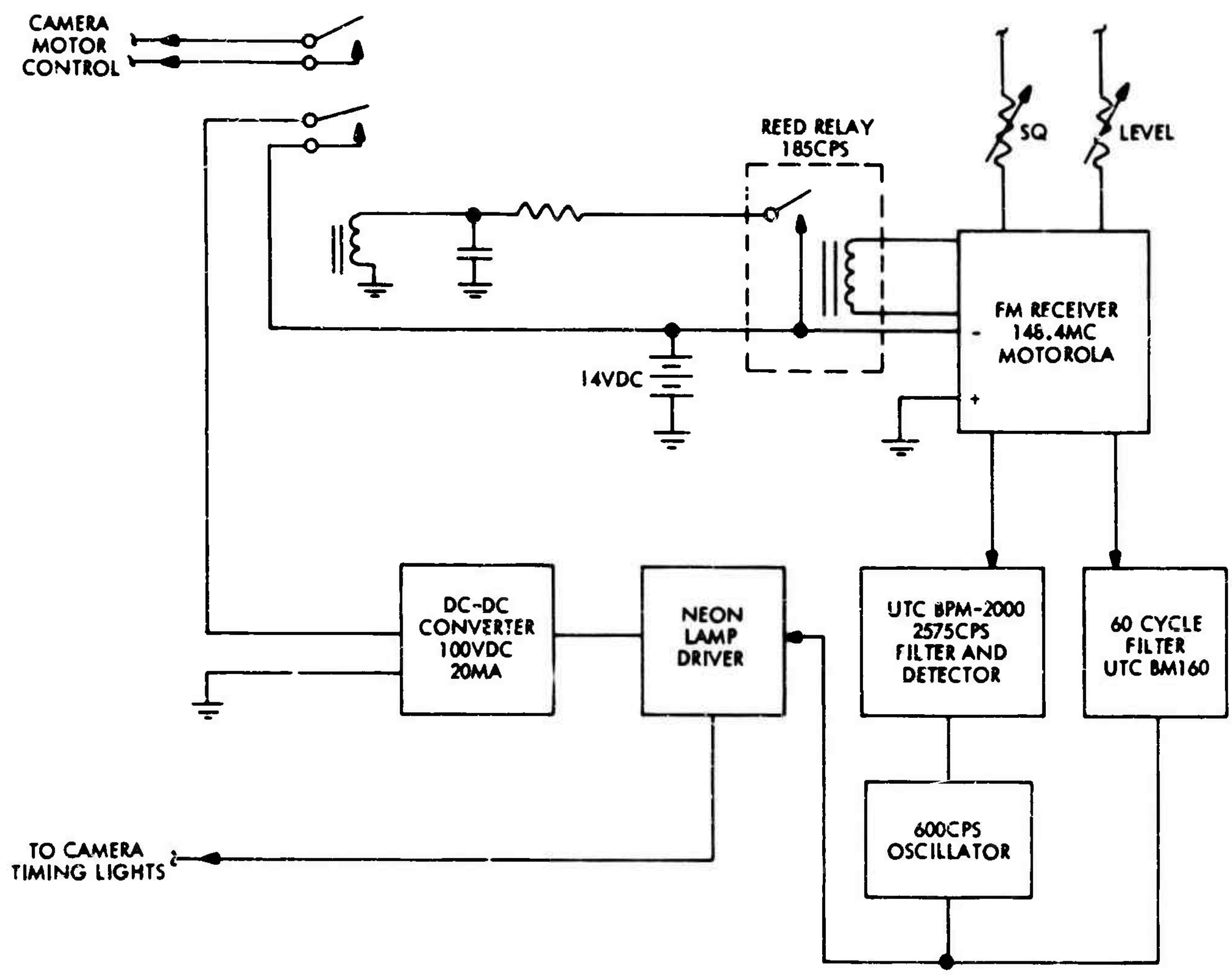


Figure 36. Camera Control and Timing Diagram

There are no special considerations in the receiving system. Each receiver will have an individual level and squelch control and a 600 ohm balanced output connected to the main signal distribution box. The received levels will be in excess of 70 microvolts.

(b) Command System. - The command transmitter will serve four functions; it will:

(1) control power in the buoys,

(2) control power to the cameras,

(3) transmit 60-cps timing to the cameras, and

(4) send "FIRE" command to the "Fire Control System."

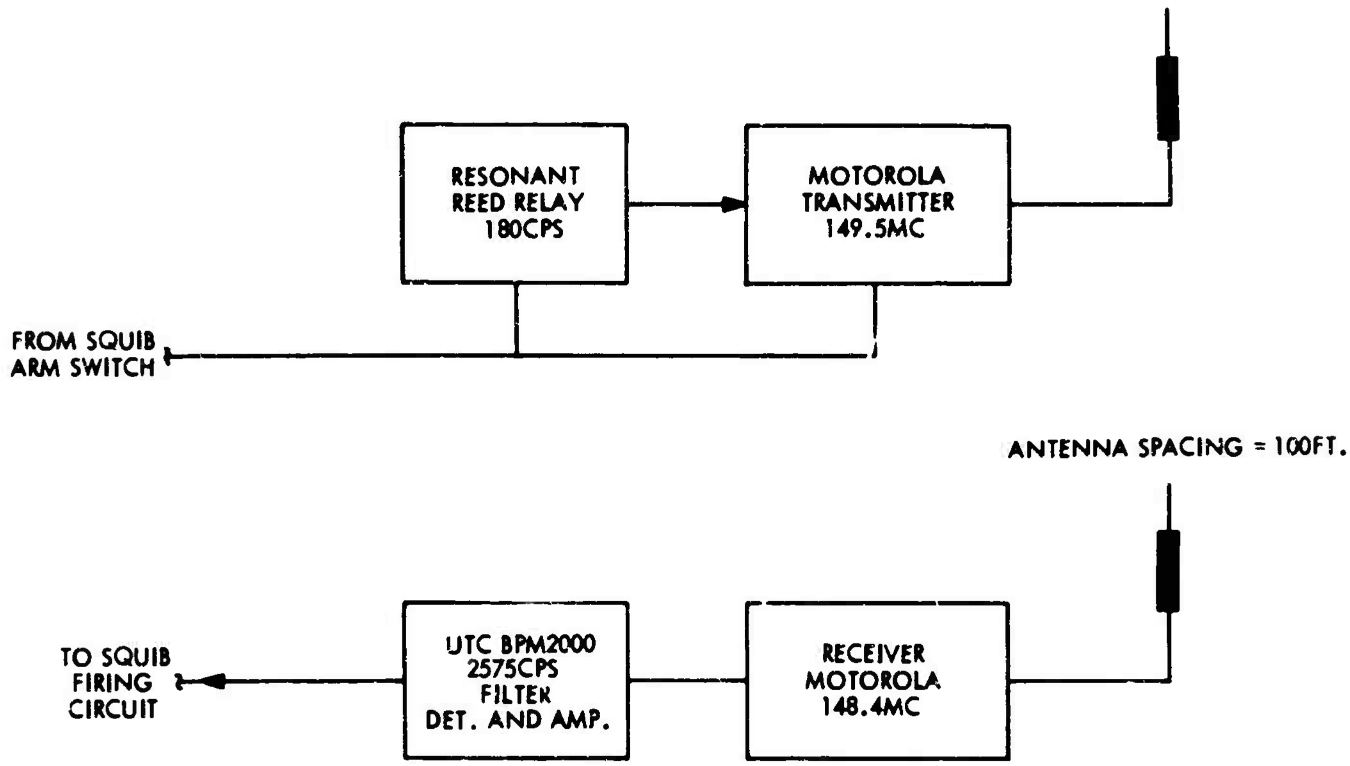


Figure 37. Fire Control Telemetry

The two power control systems will use resonant reed-controlled oscillators operating at 180 cps and 195 cps. Timing signals will be taken from the tuning fork oscillator, which is used as a reference signal in the tape recorder power system. The 60-cps signal will be used directly with only the signal amplitude being controlled. The fourth signal to be transmitted will be generated by a separate 2275-cps oscillator, and will be on the air for only a short time. An L-C filter will be used in the system so that the exact time delay may be measured and maintained.

The transmitter recommended for the command system is a Motorola L43 GGB AC utility, operating on a carrier frequency of 148.4 mc, with an output power of 25 watts. Some modification of this unit will be required so that the 60-cps timing may be transmitted. This modification consists of providing an input directly to the modulator and operating the modulator filaments on dc. The receiver portion of the L43 GGB may be used to receive the "ARM" signal from the fire control system. Again, the decoder will be a resonant reed relay.

5. Wave Measuring Systems

The wave measuring systems are of two types:

(a) Deep-Water System

(b) Near-Shore System

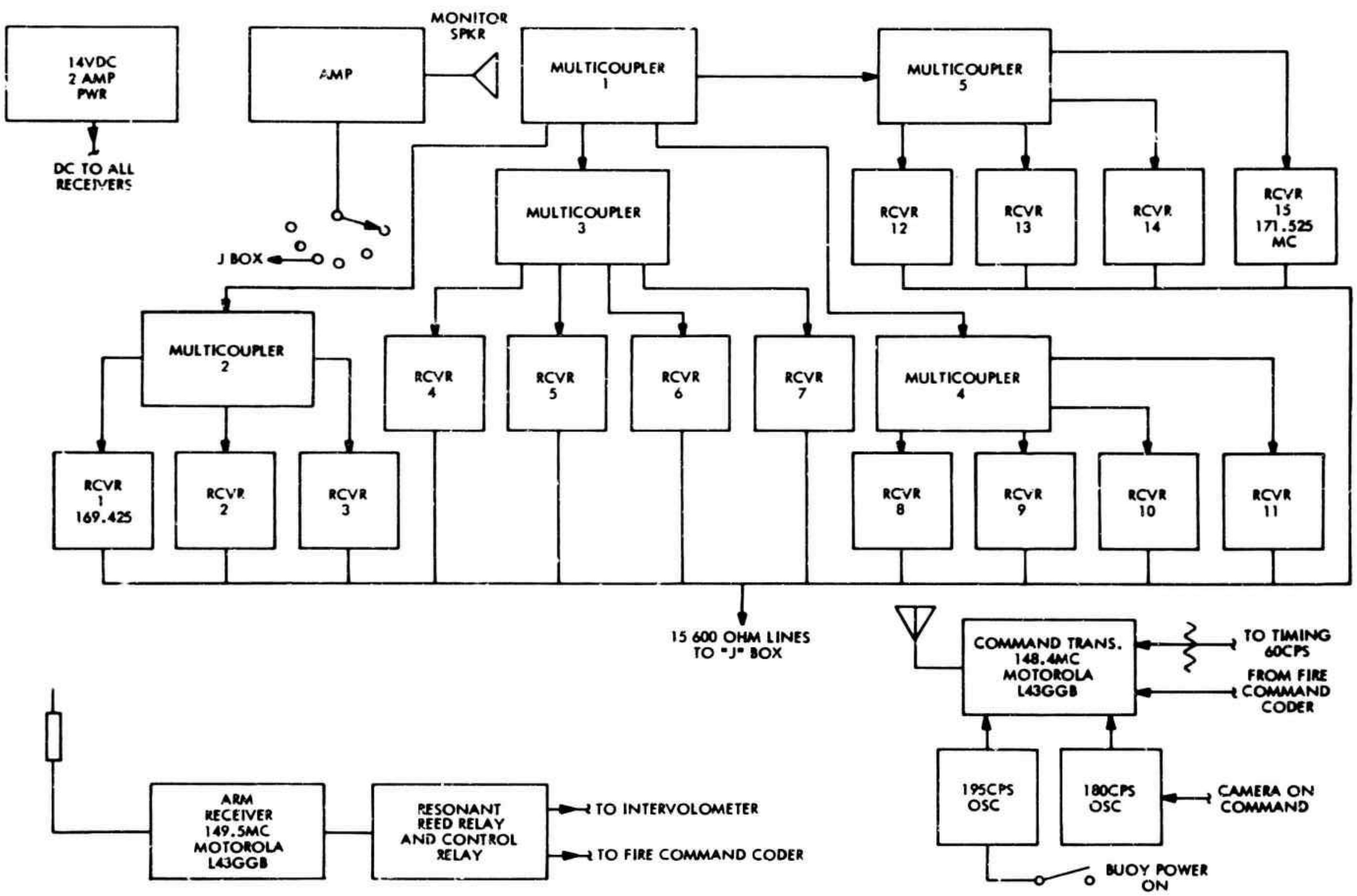


Figure 38. Telemetry and Command Shore Station Diagram

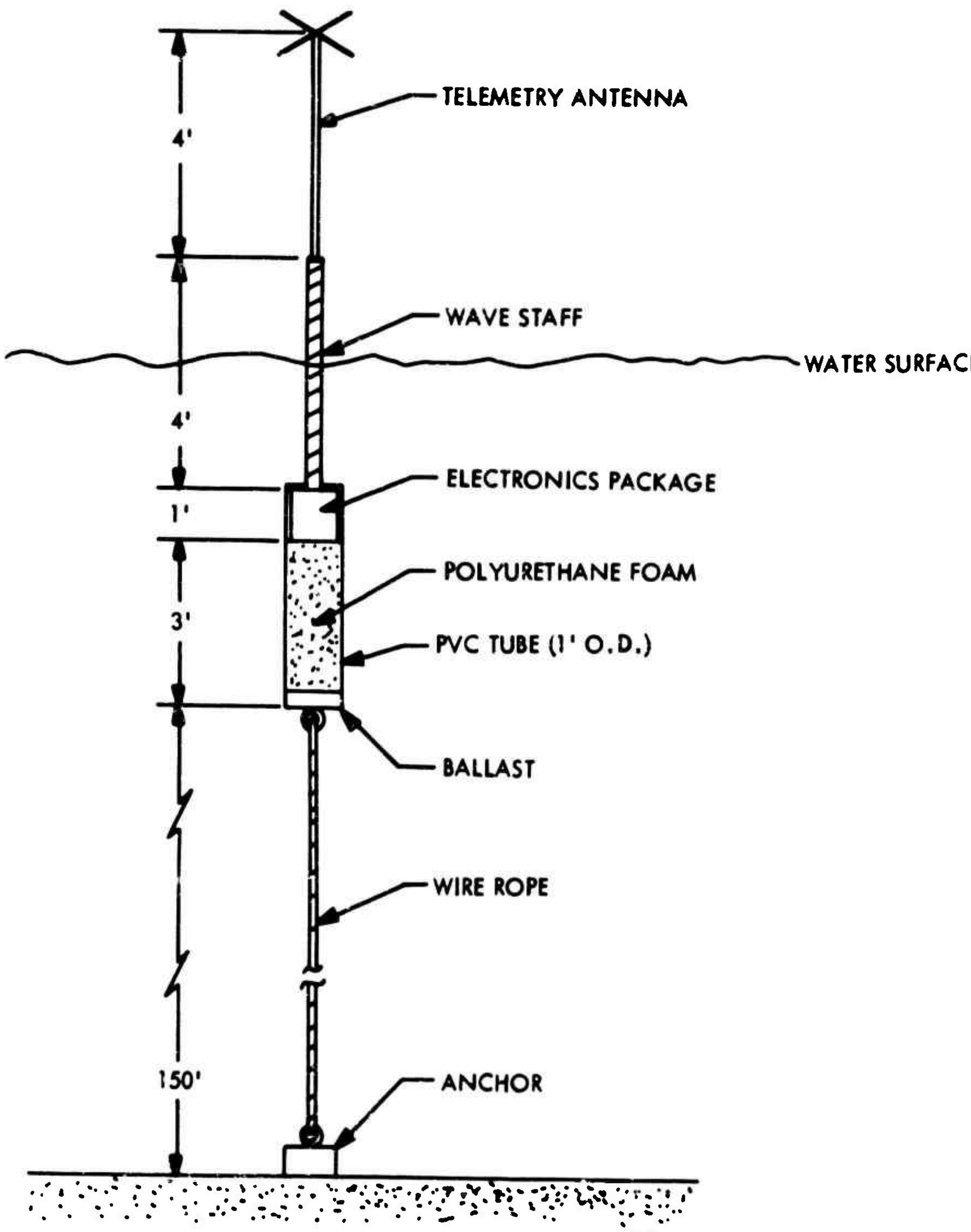


Figure 39. Deep-Water Wave Measuring System

(a) Deep-Water System (Figure 39). - The telemetry antenna and wave staff have been discussed above (sections 3 (e) and 2 (a) respectively). The PVC tube containing the polyurethane foam forms a buoyant subsurface spar with a pocket approximately one foot deep at the top to allow placement of the electronics package. The anchor is a 7-gallon container of concrete. The ballast at the bottom of the spar is used to insure stability because the electronics package is located at the top.

A weight distribution diagram of the system is shown in figure 40 (an arrow directed upward indicates positive buoyancy, and arrow directed downward indicates negative buoyancy).

Three waterproof electrical connectors are associated with the electronics package. One will connect the wave staff resistance wire into the electronics. The other two are used to transmit the signal from the BCO to the recording instrumentation on shore, one (coaxial type) for the deep-water system and the other (2-conductor) for the near-shore hard-wire stations. This arrangement allows the same type of package to be used regardless of location.

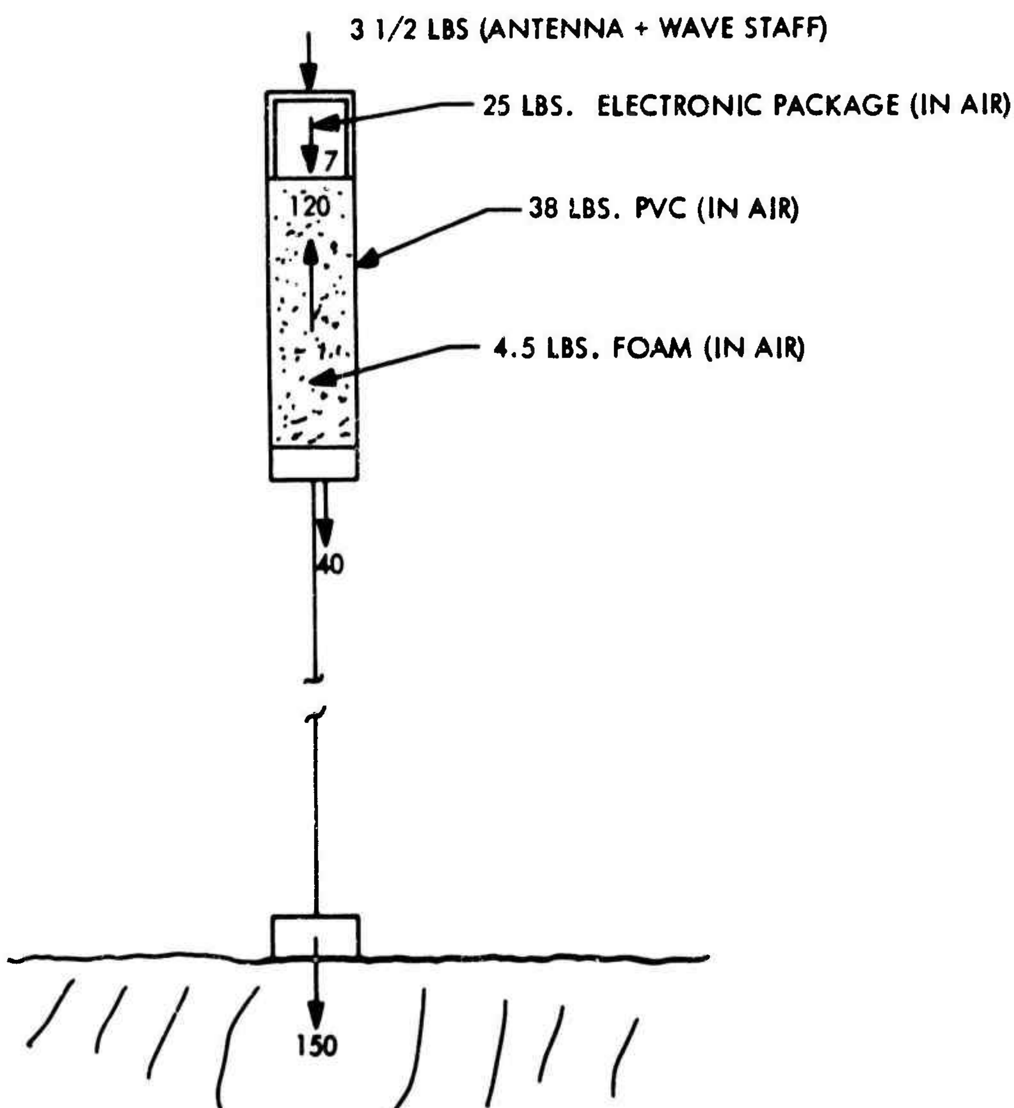


Figure 40. Weight Distribution for Deep-Water System

Installation of the deep-water system would be accomplished by lowering the anchor to the bottom with a precut wire rope attached to the spar buoy. This positions the top of the buoy two feet below the water surface. After the spar and anchor have been installed, the electronics package, with wave staff and telemetry antenna attached, can be lowered into the pocket in the spar. Once the initial installation of the spar is accomplished, the system may be serviced from a skiff (without divers in water) by merely taking hold of the wave staff and pulling up the attached electronics package. For replacement the reverse procedure is used to lower the package into the pocket in the spar. Visibility should not be a problem because the pocket is only two feet under the surface of the water.

The water shock pressure (figure 41) will not cause any appreciable damage to the spar. If the shock should crack the PVC tube, the foam filling will still provide the necessary buoyancy.

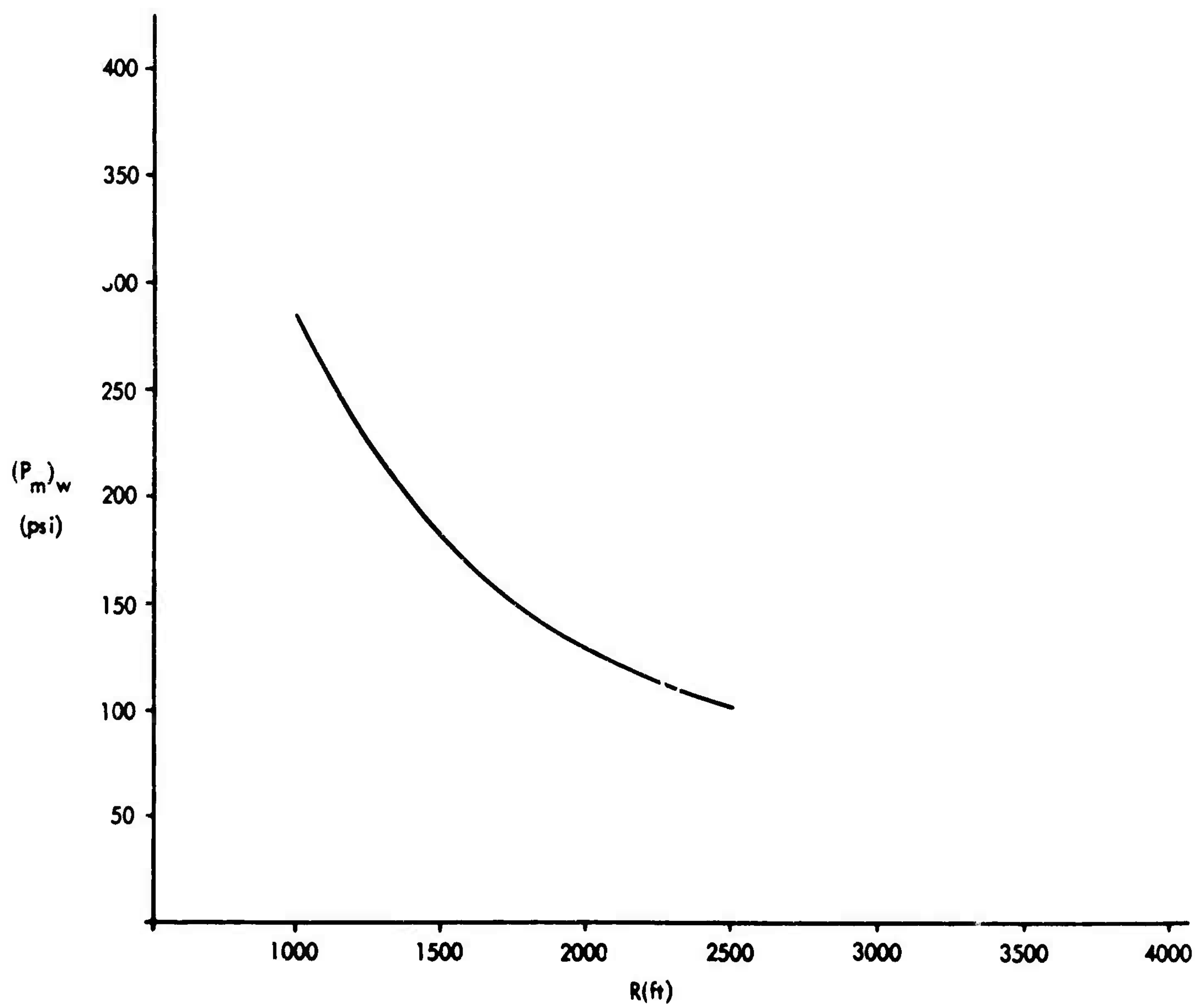


Figure 41. Peak Water Overpressure $(P_m)_w$ vs Range R for Contained Burst (10,000 Pounds TNT)

Wave action may cause the spar to oscillate (figure 42) about the wire rope support point; this would introduce errors into the measurements. The natural rotational frequency (in air) is given by:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{J}} \tag{1}$$

where

f_n = natural frequency

K = restoring torque

J = mass moment of inertia of spar about pivot

For small angular displacements, the quantity sin θ in figure 42 simply becomes θ and the restoring torque K becomes Ba.

$$J = \frac{mL^2}{3} \tag{2}$$

where

m = mass of rod

L = length of rod

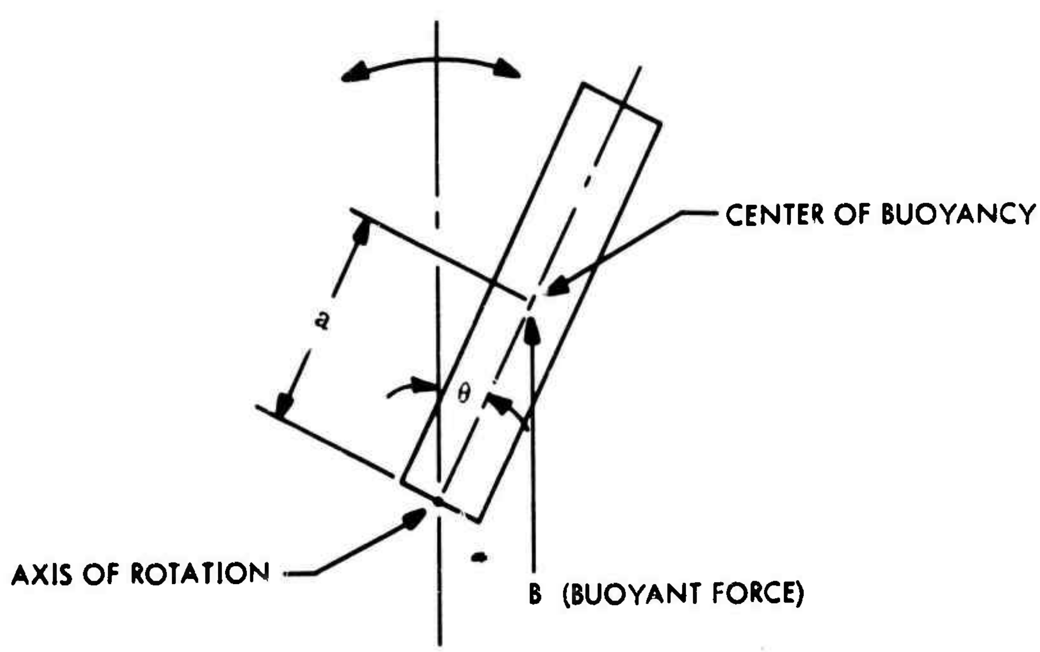


Figure 42. Oscillation of Spar

Since the surrounding medium is water and not air, a virtual mass must be added to the mass of the spar. The total mass m_t is:

$$m_t = m + 0.5\ m_v \tag{3}$$

where m_v = mass of water whose volume is equal to volume of spar. Using values shown in figure 40, the natural frequency of the spar is,

$$f_n = \frac{1}{2\pi} \sqrt{\dfrac{\dfrac{(70)\ (2)}{\frac{111}{32} + 0.5\ \frac{205}{32} \quad (4)^2}}{3}} \tag{4}$$

$$f_n = 0.318 \text{ cps}$$

Assuming the period of the waves to be measured is about six seconds; the natural frequency of 0.318 cps for the spar respresents, approximately, the second harmonic of the wave frequency. It is possible, therefore, that sufficient energy from the second harmonic of the waves may be coupled into the spar system so as to produce motion. Hence, this should be investigated rather carefully (one or two prototype spars should be built and tested in a wave environment) before the design of the spar can be finalized.

The deep-water system can not be used in water which is less than 10 feet deep.

(b) Near-Shore System. - The near-shore wave measuring system (figure 43) is much simpler than the deep-water system. It will utilize hard wire both for power and for transmitting the signal into the recording instrumentation. Only a BCO must be located at each wave staff, thus the package will be smaller than the electronics package required for the deep-water system.

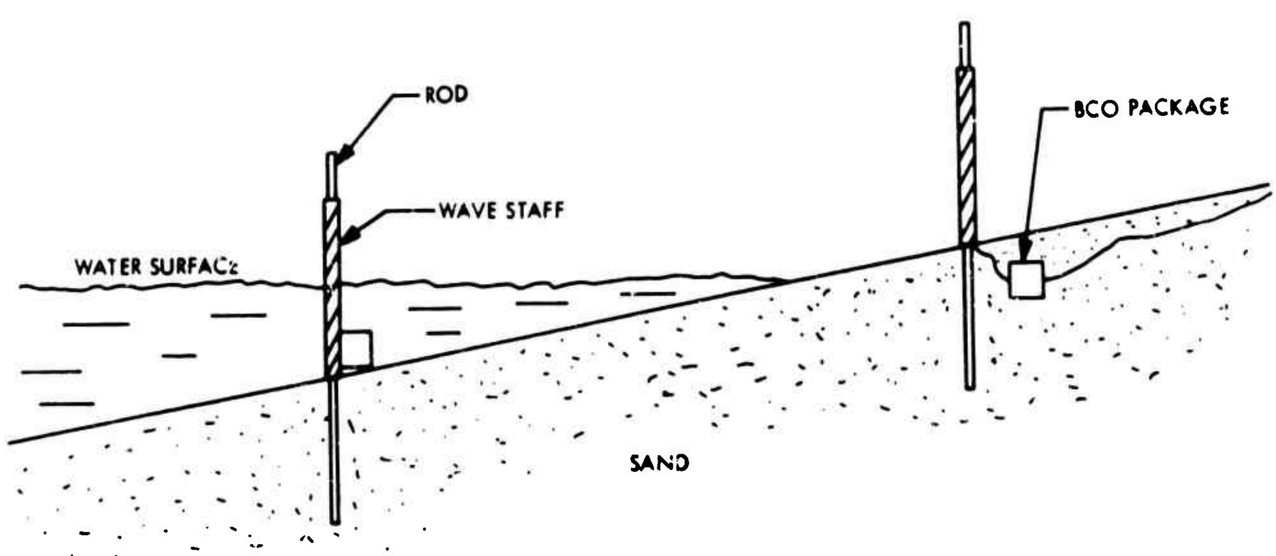


Figure 43. Near-Shore Wave Measuring System

To install the near-shore system, an iron rod first is driven into the sand to act as a support. Then the wave staff is placed over the rod and clamped in place. Because the electronics package is quite small, it may be attached directly to the wave staff and the hard wire run along the bottom up onto dry land, as shown in the left hand portion of figure 43. If it is concluded that the package and wire will cause too much interference, as it may in very shallow water or near the water's edge, then the package and wire can be buried and the beach regraded as shown in the right hand portion of figure 43.

(c) Overpressures. - Both the peak water and air overpressures (figures 41 and 44 respectively) have been considered.

The peak water overpressure caused by a contained burst of TNT can be found from*

$$(P_m)_w = 2.16 \times 10^4 \left(\frac{W^{\frac{1}{3}}}{R}\right)^{1.13} \qquad (5)$$

where

P_m = peak water overpressure (psi)

W = charge weight (lbs)

R = slant range (ft)

Specific values have been calculated for a 10,000-pound TNT charge and these have been used to construct the graph in figure 41.

The peak air overpressure $(P_m)_a$ from a surface burst of 10.000 pounds of TNT is shown in the graph of figure 44.

6. Photographic Coverage

To complete the range instrumentation, a somewhat extensive photographic system is required. Areas of consideration include shot point and plume, wave reflection and refraction, wave runup, and documentation.

(a) Shot Point. - To examine the plume and shot asymmetry, high-speed, slow-motion movie cameras are required. For this purpose, three Fastax cameras with telephoto lenses should be sufficient. Three camera locations (figure 3) approximately 120° apart should enable detection of shot asymmetry. Two of the cameras (Paoha Island and North Crater) would operate at 900 frames per second while the third (on the tower in the beach modification area) would operate at 450 frames per second. These two speeds allow easy comparison of the photographs from all three cameras. The cameras are turned on during the programmed countdown by means of the telemetry command system.

* Cole, Robert H., Underwater Explosions.

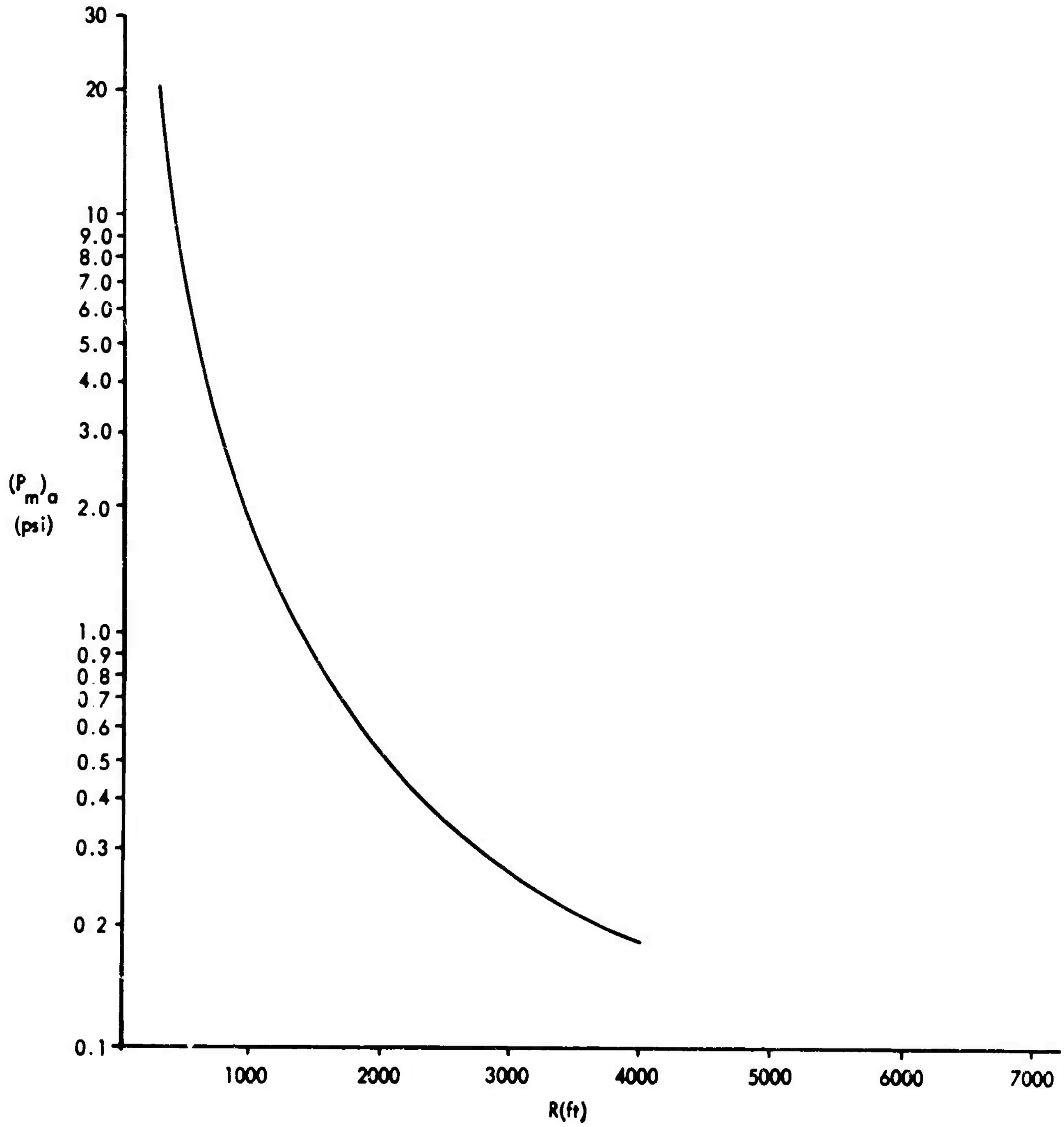


Figure 44. Peak Air Overpressure $(P_m)_a$ vs Range R for Surface Burst (10,000 pounds TNT)

(b) Wave Reflection and Refraction. - Photographs of wave reflection and refraction are best obtained from vertical aerial shots, from either a fixed-wing or rotary-wing craft. As a stable platform (especially for extended period of time), the helicopter is the logical choice. This coverage would be desirable, but is not required by the runup program.

(c) Wave Runup. - Photographic coverage of runup phenomena is mandatory. It allows the recording of the wave time history and provides information on wave form changes not directly obtainable from the other instrumentation. For this purpose, four 16-mm Arriflex cameras with 200-foot magazines would give minimum desired coverage. Three of these cameras would be mounted in the runup zone, oblique to the shore; the fourth would be mounted on the tower in the modified beach area for high-angle photographs of the runup phenomena.

(d) Documentation. - For documentation purposes, a single 16-mm Arriflex is sufficient.

D. RANGE OPERATION

This section of the report deals with the actual execution of the proposed field program at Mono Lake. As such, it is concerned with the various activities involved in the mobilization, operation, and demobilization of the range. Essentially, this means installation of instrumentation systems, preparation of shore and water facilities, procurement and deployment of vehicles, craft, communications, explosives, and personnel, and the operation of facilities and equipment during the test phase, etc.

Details on these aspects are presented as follows:

1. Charge Support System
2. Beach Modification Procedures
3. Range Mobilization
4. Range Operation
5. Range Demobilization

1. Charge Support System

(a) Charge Fabrication. - The charges required for the tests will be cast at the Naval Ammunition Depot (NAD), Hawthorne, Nevada. A minimum of 10 charges will be fabricated, similar to those furnished to the Hydra Program and as discussed in the report USNRDL-TR-727, dated 3 October 1963.

The Hydra molds are recessed for placement of nylon webbing straps before the charge is poured. These straps form a convenient holding arrangement, allowing the charge to be lifted from the mold and handled at dockside and on board ship.

The basic charge is 68 inches in diameter and consists of 10,000 pounds of HBX type explosive. The charges will be stored at NAD and delivered upon demand, one at a time, to the Mono Marina

for transport to the shot point by a self-propelled pontoon barge. Fusing will take place aboard the barge, just prior to positioning the charge underwater. The fuse will be connected by hard wire to the firing control position on Paoha Island, located approximately 1-1/2 miles northwest of the shot point. No permanent charge storage facility is anticipated in the Mono Lake area because of (1) the accessibility of NAD to the area, and (2) the problems connected with the long-term physical security of high explosives.

(b) Handling. - The charges will be handled with a 25-ton crane (aboard the barge), which will transfer the charge from the delivering truck to the barge for transportation to the shot point. These operations will be conducted at Mono Marina, which is adjacent to US Highway 395. Existing inshore shallow water conditions and limited boom length require both the construction of a pontoon wharf at the marina loading site and limited dredging to obtain the necessary water depth.

(c) Support System. - The underwater weight of the 10,000-pound charge may be found from:

$$W_w = 10,000\left(1 - \frac{\rho_w}{\rho_x}\right) \tag{6}$$

where

W_w = underwater weight

ρ_w = density of water

ρ_x = density of explosive

The charge is 68 inches in diameter, so:

$$\rho_x = 104 \text{ lbs/ft}^3$$

The water at the test site is assumed to have:

$$\rho_w = 65 \text{ lbs/ft}^3$$

Therefore:

$$W_w = 3,750 \text{ lbs.}$$

The problem of supporting the charge for a shot becomes quite involved if (as is usual in tests of this nature) it is required to keep the supporting equipment as small and as removed from the charge as is feasible. The haul-down method which was used on the Hydra program was both elaborate and costly.

With the requirement that the detonation depth may vary from the surface to a maximum of 130 feet, three support systems have been considered: (1) inner-tube flotation, (2) epoxy jacket, and (3) styrofoam tripod.

(1) Tube Flotation. - Each charge is to be supported by a 1/2-inch wire rope connected to the handling sling of the charge and to a three-point surface-tethered flotation unit. The flotation unit consists of a large inner-tube fitted with an underwater sling for a single-point attachment to the 1/2-inch wire rope. This method (figure 45) ensures a 10 percent positive buoyancy of the entire system yet is both light and convenient to handle and, because of its low cost, can be considered expendable. The entire support system lies in a vertical plane above the detonated charge. There should be a minimal distortion of the bubble and plume with this type of system.

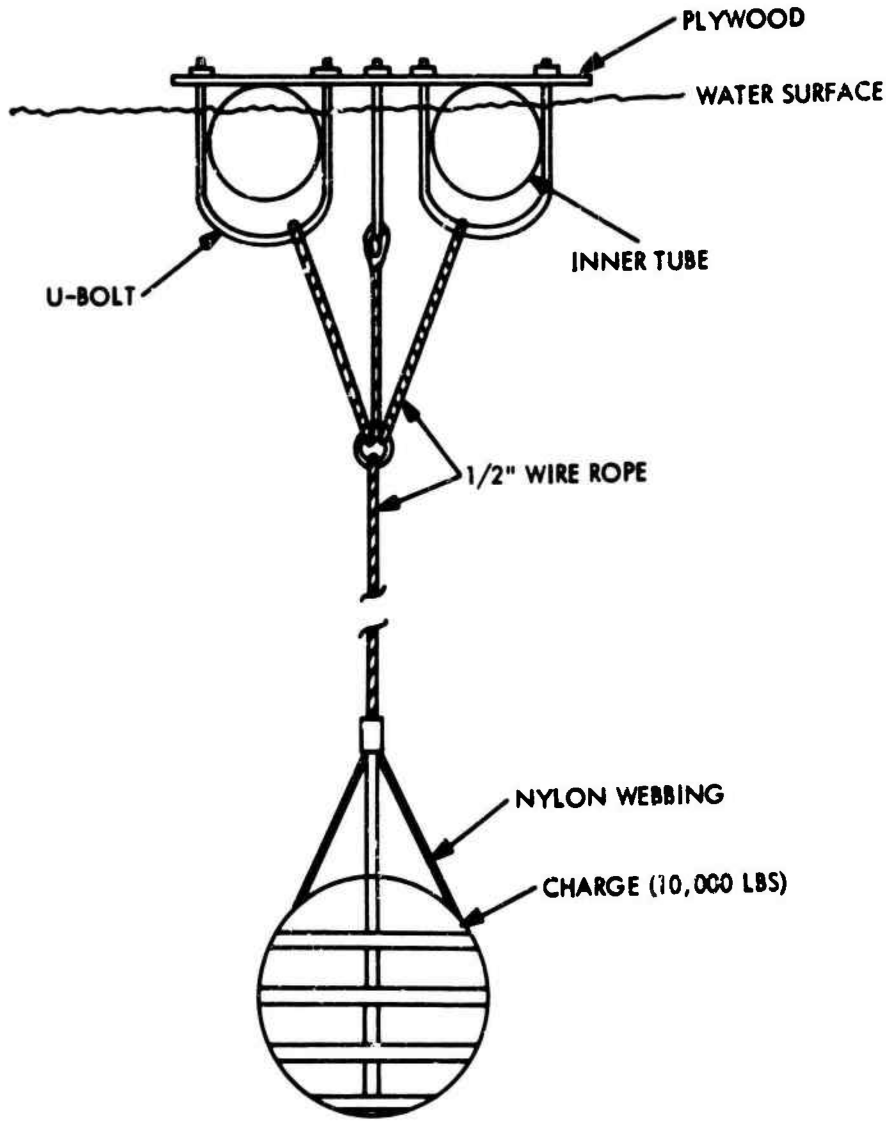


Figure 45. Charge Support System, Deep Shot

A large size inner-tube (such as those found on earth moving machinery) will be used for the main float. A 29.5-29 inner-tube has a buoyancy of approximately 4,700 pounds. This is sufficient to float the entire weight of the charge and the auxiliary equipment (such as the wire rope, plywood, etc.).

The system shown in figure 45 can be used for deep shots or for near-surface shots. For a surface shot, the arrangement in figure 46 will be more convenient. If it is desired that a very near-surface shot be conducted, a system similar to that for surface shots can be used, but with the inner-tube on top (figure 47). The system for very near-surface shots (figure 47) is inherently more stable than for surface shots (figure 46), but in calm lake water, a surface shot-configuration can be used without much difficulty.

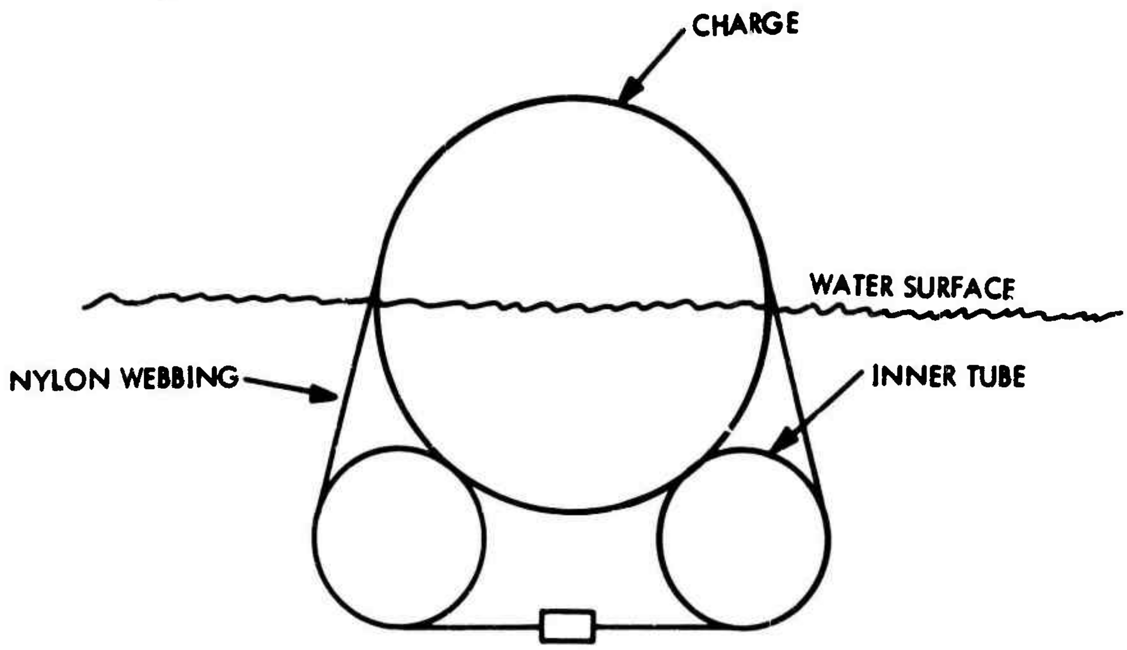


Figure 46. Positioning for a Surface Shot

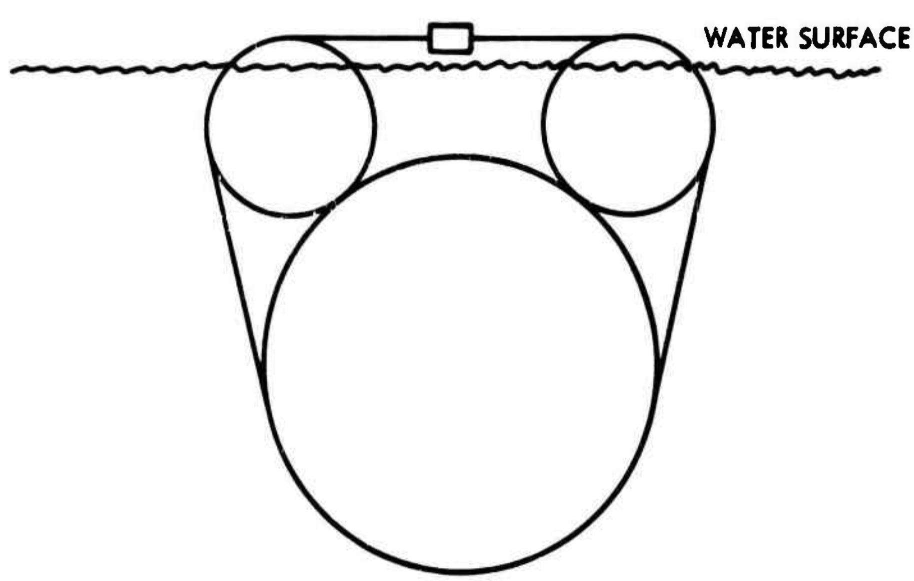


Figure 47. Positioning for a Very Near Surface Shot

(2) Epoxy Jacket. - Figure 48 shows a second method which has been suggested for supporting the charge. The outer jacket is epoxy with glass microspheres used as a filler material. This produces a material of very good structural strength (at least in compression) with a density of about 40 lbs/ft^3. The jacket can be fabricated in sections and placed around the charge prior to the handling and transportation.

Assuming that the total positive buoyancy should be 5,000 pounds, the volume V_e of epoxy required is:

$$V_e = \frac{B}{B_o} \tag{7}$$

where

B = buoyancy required

B_o = specific buoyancy, i.e., buoyancy/ft^3

For the case being considered:

$$B_o = 21 \text{ lbs/ft}^3$$

and thus:

$$V_e = 238 \text{ ft}^3$$

The outer radius of the jacket is found from:

$$V_e = \frac{4}{3}\pi(r_o{}^3 - r_i{}^3) \tag{8}$$

where

r_o = outer radius of jacket

r_i = inner radius of jacket

The inner radius r_i of the jacket is the radius of the charge, i.e., 34 inches, and r_o is found to be:

$$r_o = 4.30 \text{ ft} \sim 52 \text{ inches}$$

The thickness of the jacket is then:

$$t = 18 \text{ inches}$$

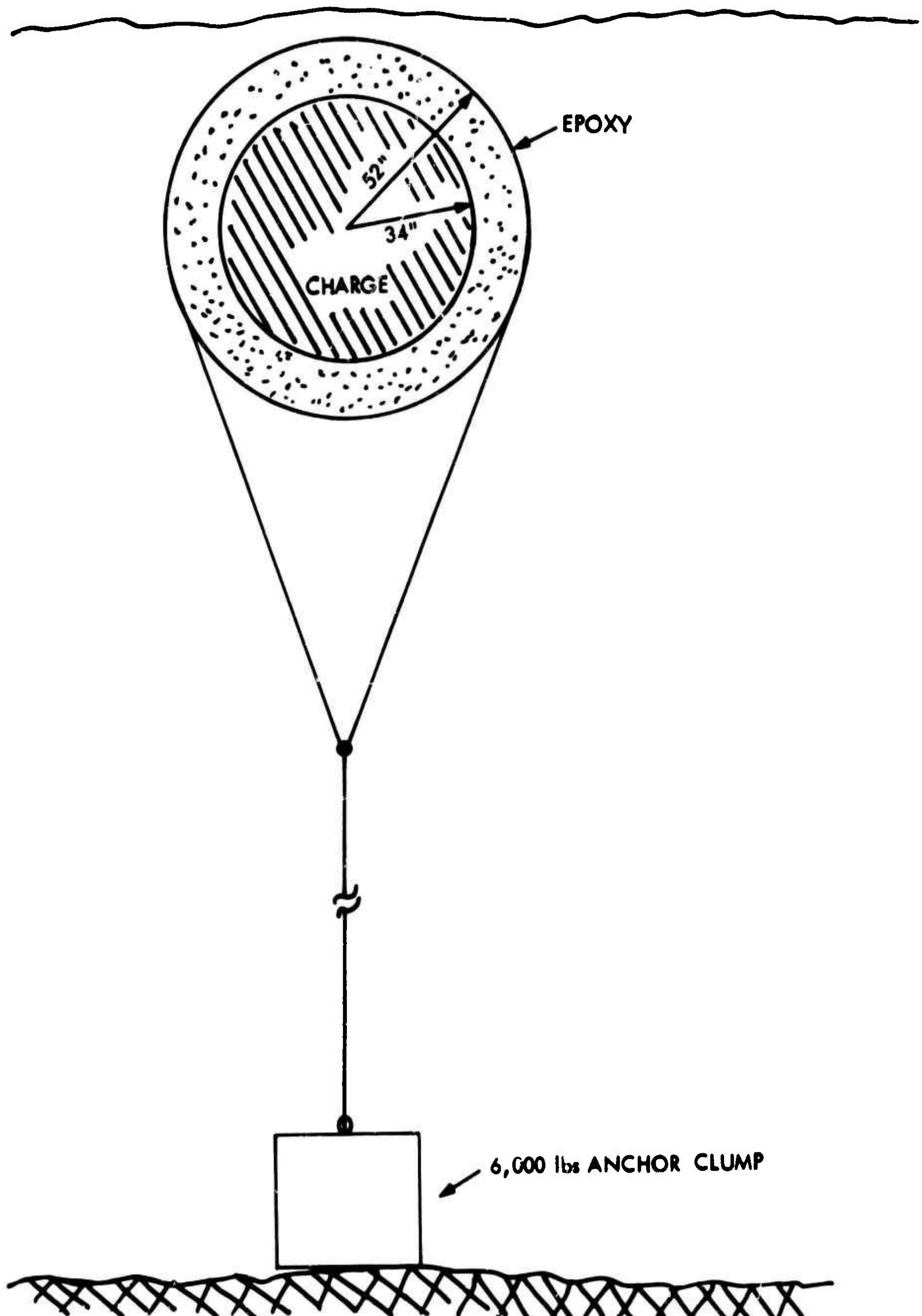


Figure 48. Epoxy Jacket Charge Support System

It is anticipated that the epoxy (being weak in tension) will easily break down upon detonation and not appreciably perturb the effects of the explosion. Recent tests conducted at Waterways Experiment Station on small charges indicate such jacket effects to be minimal or nonexistent.

(3) Styrofoam Tripod. - A third support system, suggested by Waterways Experiment Station, is shown in figure 49. This consists of a wooden tripod assembly, 18 feet on the base legs and 20 feet in height supported by three 8-foot diameter styrofoam pads. The charges would be placed on the assembly at the shore and floated to the detonation position.

(d) Charge Fusing and Firing. - All charges will be fused from the utility boat just prior to lowering to the designated water depth. It is planned that such fusing be handled by an ordnance team from NAD. At the time of fusing, the hard-wire firing line will be connected and run to the firing control area which will be manned by a member, or members, of that ordnance team from NAD. The NAD ordnance team will dictate fusing and firing line precautions to the Range Safety Officer prior to each detonation, and in the event of a misfire, will determine the cause. NAD also will disarm the charge in the event of either a misfire or cancellation of detonation and remove the charge from the test area.

(e) Timing. - The charge will be detonated by a real-time pulse transmitted via telemetry from the instrumentation trailer at the beach site, only after the firing contacts have been engaged by the Firing Control Officer on Paoha Island. The detonations can occur as late as 2 minutes

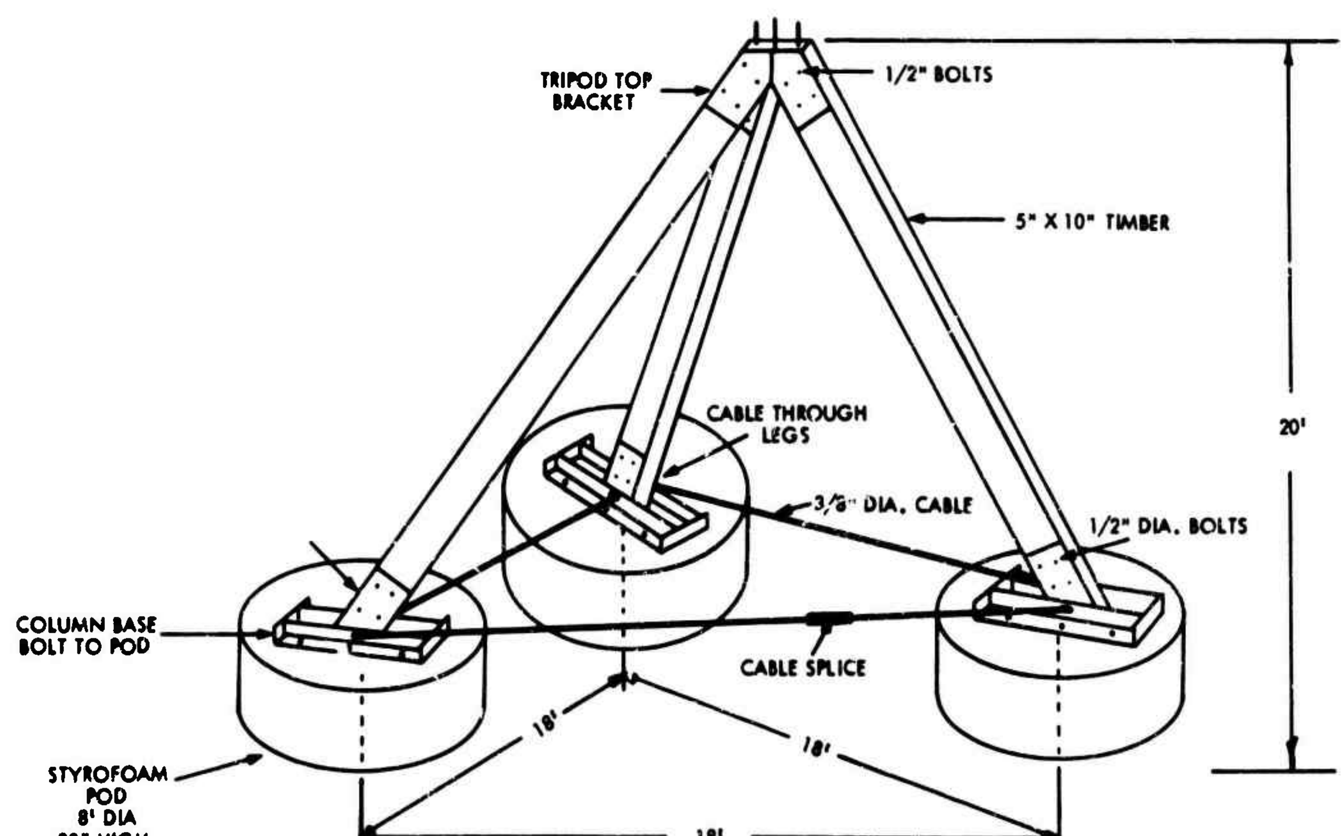


Figure 49. Styrofoam Tripod Charge Support System

after engaging the firing contacts or as early as 1 minute, but will be synchronized to the minute signal from WWV, WWVB or WWVH for "real time." This timing is described in detail in report section C. 2(g), but it should be mentioned that a countdown will exist, via another radio link, between the Range Operations Officer at the beach site and the Firing Control Officer on Paoha Island.

2. Beach Modification

The beach site chosen to be modified for the runup study is centrally located in the instrumented beach sector, and extends approximately 300 feet along the water edge and 150 feet shoreward. It is to be altered to a non-percolating, hard-surface area with a slope of 1:50 extending to at least 12 inches below the average surface level of the lake. It is anticipated that various shoreline features may be constructed in the modified area.

It is recommended that, prior to establishing the range, tests be conducted in the area to determine the best and most economical means of utilizing available materials to stabilize the proposed modified area and also to evaluate tendency of longshore currents to alter the shoreline.

At present, the recommended method of beach stabilization would be to apply a slurry of neet cement to a depth of 2 to 4 inches from the water edge shoreward with a slope of 1:50. From the edge of the cemented area, and beneath it, layers of plastic-coated screening would be securely attached to the bottom and extend into the water to a depth of no less than 1 foot. Other methods include construction of a wooden runup platform and chemical stabilization. All of these must be evaluated at the test site for a reasonable length of time (3 to 4 weeks).

3. Range Mobilization

(a) General. - The basic concept in the establishment and mobilization of a test range at Mono Lake is to use as much local labor, contractors and materials as possible, in order to reduce the overall expenditure. This concept is reflected in the scheduling, services and costs throughout the mobilization of the range.

An anticipated schedule (figure 50), which shows mobilization and operational periods from May through October, assumes a range operational period of 6 weeks. The following paragraphs describe the services, materials and functions necessary to produce an operational range for the defined task.

(b) Survey. - Prior to construction of roads and test areas, the entire range should be surveyed. Lake (figure 3) provides the only permanent beach mark in the area. Most of the beach marks, placed by the city of Los Angeles, have been moved somewhat from their original position and thus cannot be relied upon without resurvey. In addition to those locations required along the shoreline, the proposed camera position on Poaha Island should be surveyed in. Once the ground survey has been completed, a more complete bathymetric survey of the area of immediate interest may be conducted. Resurvey of the bathymetry in the surface zero area is required after each shot. Additionally, the establishment of temporary beach marks at this time will facilitate the precise locating of

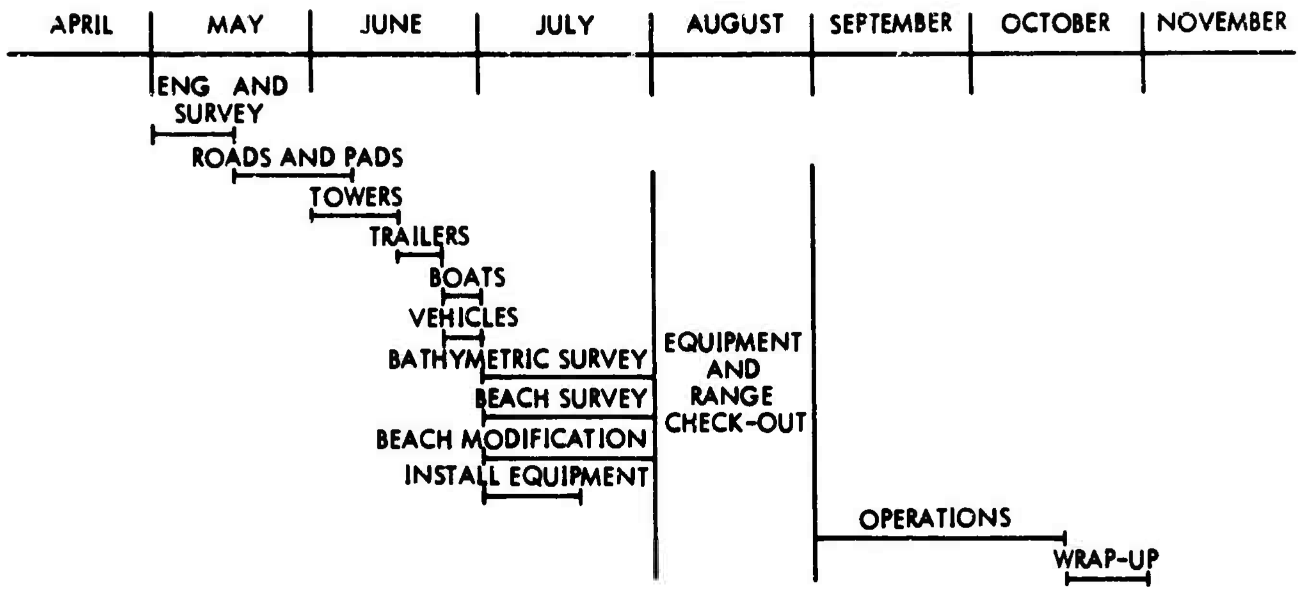


Figure 50. Range Mobilization Schedule, Mono Lake

all sensors installed during the operation phase. Dangerous shoal areas in the lake should be marked with buoys during the early phases.

(c) Roads and Pads. - It is anticipated that a hard surface access road (asphalt) will be constructed from State Highway 120 to the test site area. Two hard surface pads will be required along these roads (figure 51). For the vehicular traffic anticipated (not to exceed 15 tons), approximately 2 miles of hard surface road 22 feet wide and 3 inches thick will suffice. In addition to the hard surface roads, beach service roads are required along the test area for approximately 2 miles. Such roads can be constructed of chain link fence and 2" x 12" x 12' rough Douglas Fir planking. The hard surface road construction can be accomplished by firms in Bishop. Lumber in the quantities anticipated (21,600 board feet) also can be obtained in Bishop; however, a minimum of 2 weeks lead time is necessary. The chain link fence can only be supplied from Los Angeles, San Francisco, or Reno. District 9 of the California State Division of Highways at Bishop should be contacted concerning road attachment to Highway 120.

(d) Towers. - Both photographic and communications towers are required for the range operation phase. Each of the towers would be a minimum of 44 feet in height with a platform on top of those used for photographing. The structures would be guyed to produce a very stable platform for the cameras (it is probable that operations would be conducted during a zero wind condition). Figure 52 shows the communications path from the site area to Lee Vining. At the site, the antenna array would be mounted on the camera tower, while at Lee Vining, either a 50-foot antenna is required or a shorter antenna must be mounted on the hill behind the town.

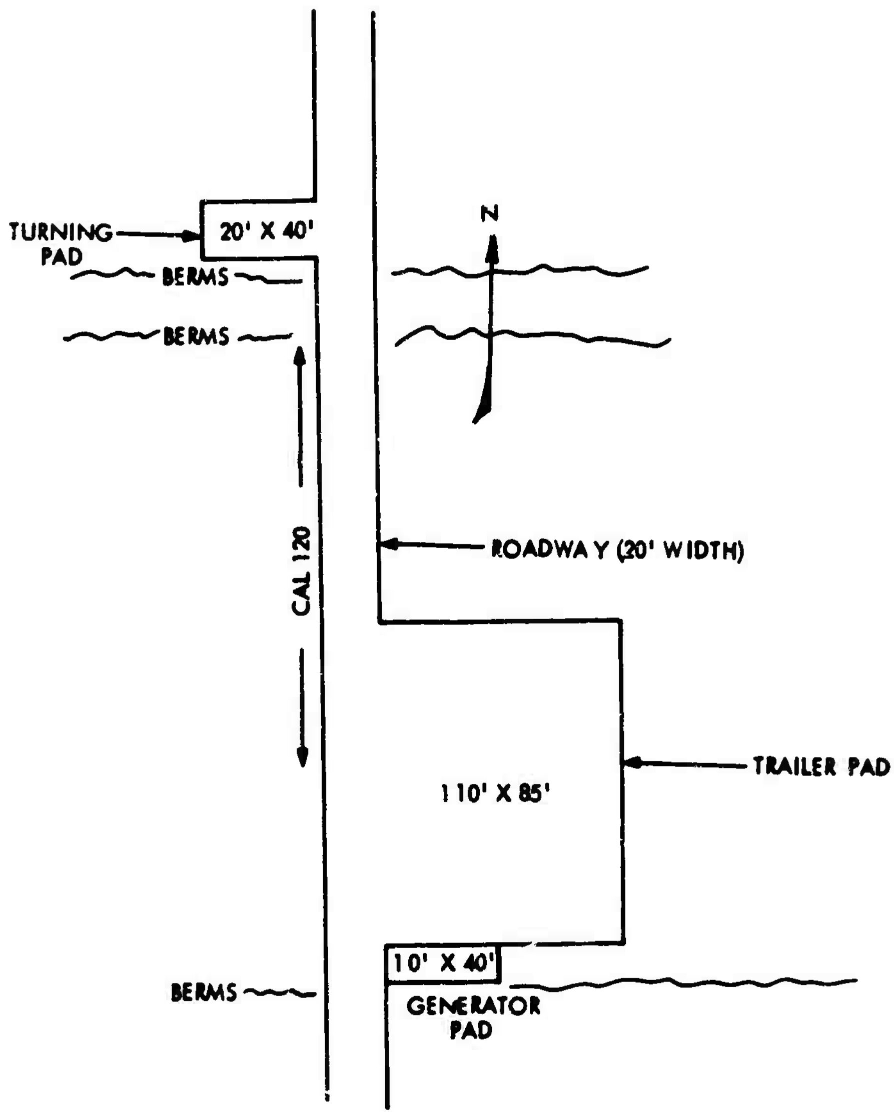


Figure 51. General Location of Roads and Hard-Surface Pads

(e) Trailers. - The number of trailers required for the operation is dependent on whether the field personnel are quartered in trailers or in local motels and other establishments. Those trailers required for only the operation phase include:

1) Office Trailer (4 offices)
2) Communications/Instrumentation/Electronics Trailer
3) Machine Shop Trailer

If trailers are required for messing and berthing, those additionally required would be:

1) Berthing Trailer (26 men)
2) Messing Trailer (20 men)
3) Sanitation Trailer (6 showers and 6 lavatories)

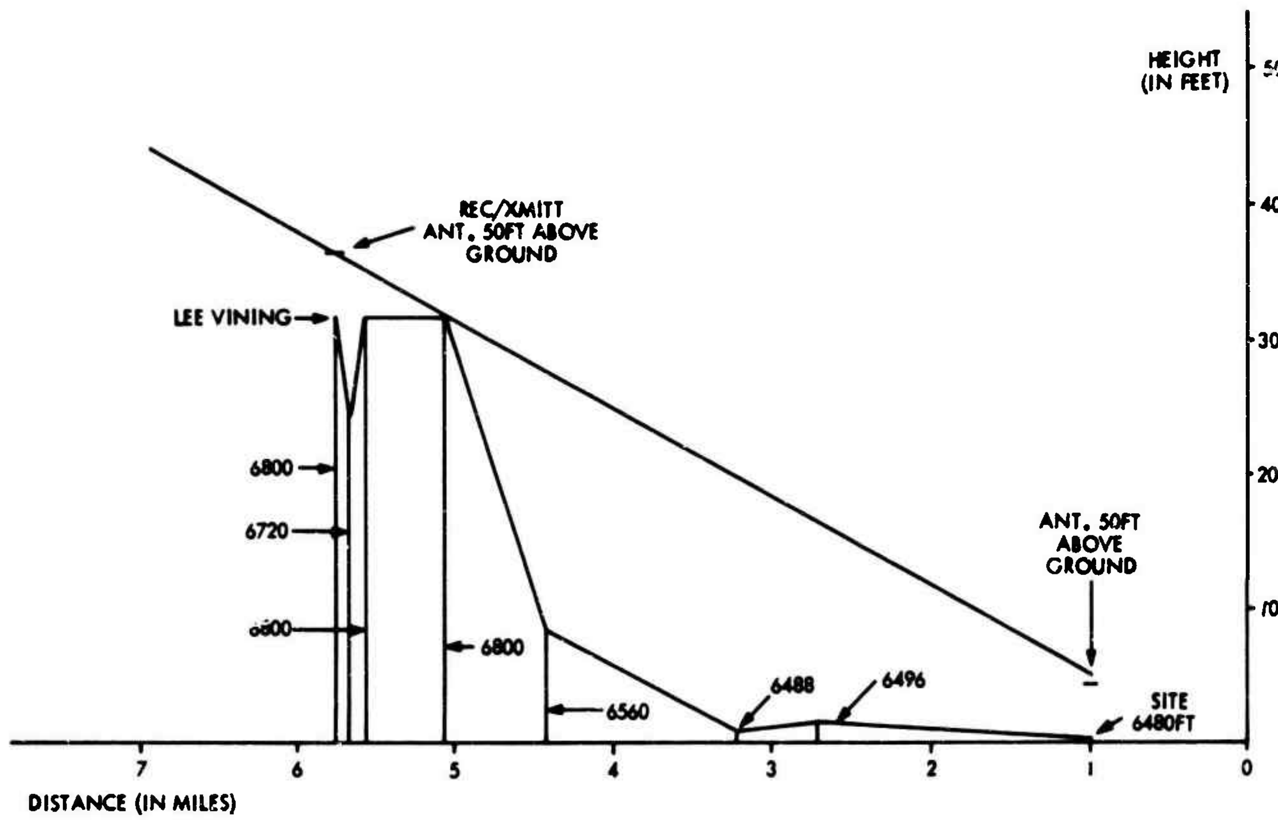


Figure 52. Communications Path from Site to Lee Vining

Figure 53 shows a type installation plan for the maximum number of trailers. Along with the living trailers, associated facilities such as sanitation, fuel, water, etc., must be installed. Additionally, a septic tank must be constructed, propane storage tank installed, water tank constructed and installed, and fuel tanks installed. Eating utensils, bedding, dishes, laundry service, etc. are available from Bishop and Los Angeles. Some portable toilets are required at the far ends of the construction area. Should the men be quartered in town, many of the above facilities are not necessary.

(f) Water. - This is available (at no cost) from the State Division of Highways in Lee Vining; however, it must be trucked to the site.

(g) Fuel. - Propane, if required for heating the trailers (and cooking), is available from Bishop. Premixed boat fuel can be delivered on site (and stored) from Lee Vining. Gasoline is available from Lee Vining and can either be purchased there as required or delivered and stored on site.

(h) Power. - Either generators or pole power (Southern California Edison) can be used, although the cost of extending commercial power to the site area far exceeds the cost of equivalent generator power. Additionally, some power must be supplied to the remote cameras. Should pole power be used, the telephone lines (Interstate Telephone and Telegraph) can utilize the same poles thus eliminating the radio link to Lee Vining.

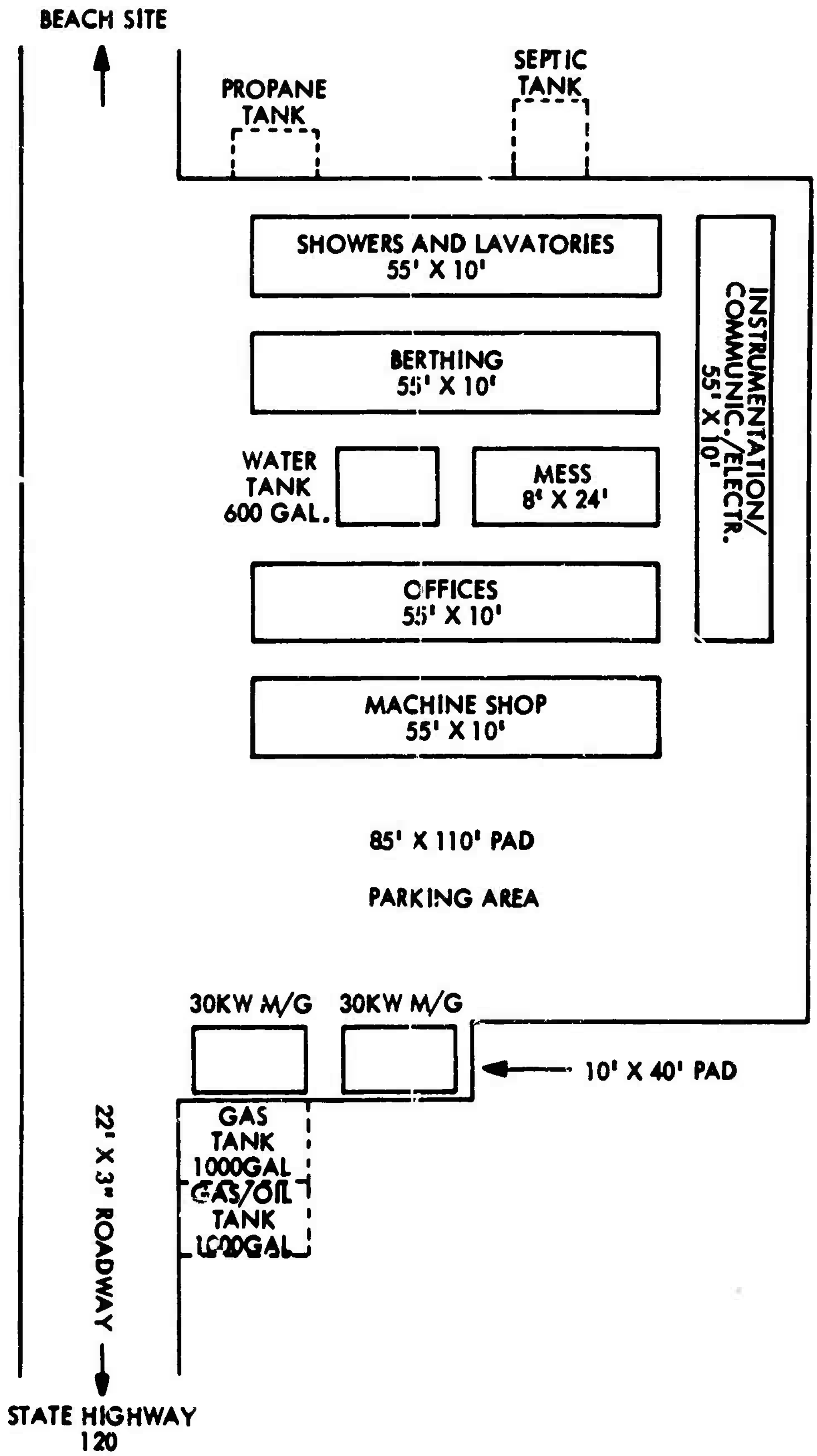


Figure 53. Trailer Complex Detail

(i) Vehicles and Boats. - A variety of vehicles and boats are required for the mobilization and operation phases. These include:

1) two 1/4-ton trucks (4 wheel)
2) two 3/4-ton trucks (4 wheel)
3) three 14-foot runabout boats (10 hp)
4) two 17-foot work boats (65 to 75 hp)
5) one motor grader and scraper
6) one dump truck
7) one water truck and/or water trailer
8) one 12-ton crane (cherry-picker)
9) one 100-ton crane (heavy duty)
10) one 30' x 35' pontoon barge (w/two 22-hp outboards)
11) one rotary or fixed-wing aircraft

(j) Warfs and Docks. - Construction of boat landing facilities is required in three locations: 1) Mono Marina, 2) Pahoa Island, and 3) beach site. A pontoon wharf 10' x 14' should be adequate. In the site area, it is anticipated that a larger dock area would be necessary. For this purpose, a 50' x 12' 3/4-ton dock would be required.

(k) Communications. - Immediate installation of communications equipment is required to facilitate the overall range mobilization. Figure 54 shows the communications and paging system at the test site, while figure 55 shows the office communications at Lee Vining.

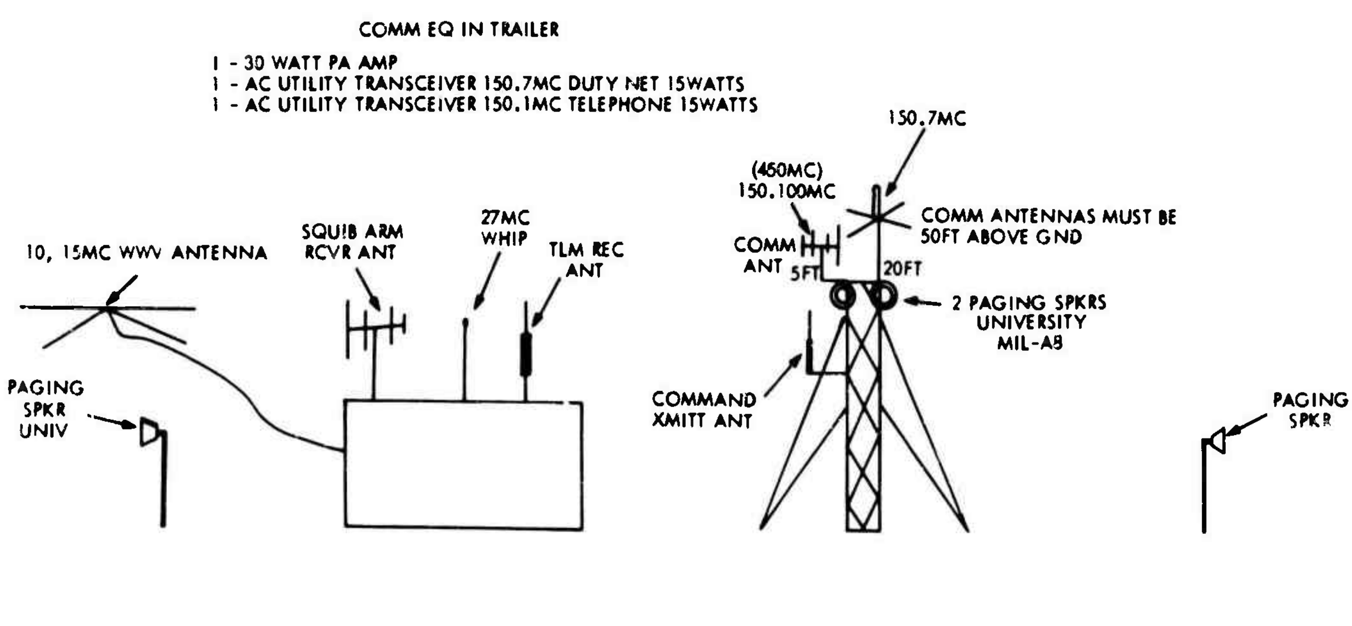


Figure 54. Communications and Paging System

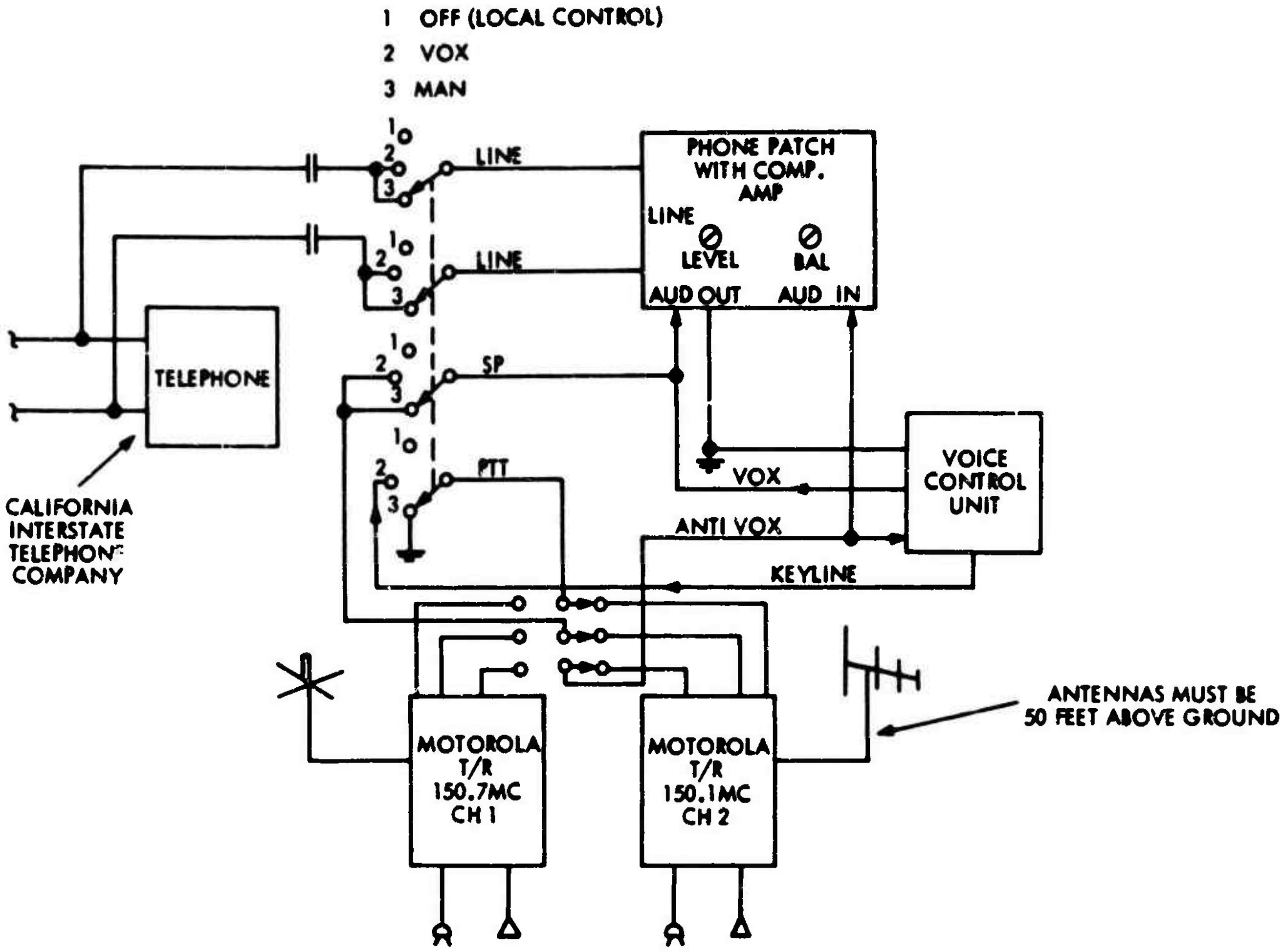


Figure 55. Office Communications Equipment, Lee Vining

(1) Photography. - The recommended types of photography have been indicated in section II, C, 6. To adequately meet all the requirements except the aerial photography, three 16mm Fastax, five 16mm Arriflex and one 35mm camera would be adequate. Additional equipment for the Fastax camera would include two 600mm f4.5 lenses with cradles, one 300mm f4.5 lens with cradles, camera mounting, three goose controls with cables, and 30 rolls of black and white film. Additional equipment for the Arriflex camera includes one 16mm lens, two 25mm lenses, two 50mm lenses, two 200-foot magazines, battery packs and converters, one tripod, 40 rolls (16mm x 200 feet) of color film, and 10 rolls (16mm x 100 feet) of color film. Almost any 35mm camera will suffice. Twenty rolls of 35mm color film, an exposure meter and flash equipment will also be needed. The film processing should be conducted by the NOTS facility at China Lake, the USAF facility at Lookout Mountain, or some like government facility if possible. If not, adequate processing is available in Los Angeles. As noted on the schedule (figure 50), it is anticipated that the range mobilization would be completed by 31 July, allowing the entire month of August for equipment and range operation checkout prior to commencement of the operational period on 1 September 1965. Earlier testing may take place after range checkout.

4. Range Operations

Prime consideration for the project as a whole is to achieve and obtain the must usable amount of information on wave runup for the least possible expense, but in no way during the operation to jeopardize the safety, or well-being, of personnel or property. With these points well in mind, the Range Operations are established as shown on the accompanying "Operations Command Chart" (figure 56).

As each charge is detonated, NADHN will be called to deliver the next charge and preparations will commence for the arrival and placing of that charge for the following test at the earliest possible time. All recordings are to be examined; sensors, TLM and recorders checked and prepared; film removed from cameras (which will be immediately reloaded and checked out); all portable power plants refueled and checked and all communications rechecked for reliability. As each area is prepared for the next test, that information is passed to the Operation Officer. When all tasks are accomplished, the range is considered in readiness and will remain in a state of readiness until detonation time.

It is estimated that to operate the range, about 22 men will be furnished by the contractors. It is recommended that the following personnel be furnished as GFE:

One Ordnance team of approximately four men
One Corpsman (w/first aid equipment)

It is also recommended that arrangements be made with NOTS China Lake Facility for immediate processing of all film taken during each test, so that necessary changes or modifications may be recognized and accomplished prior to the next test.

Upon completion of the test operations, it is anticipated that the area can be demobilized within a 2-week period by removal of trailers, towers, generators, tanks, cameras, sensors and cables (with the exception of the paved road to the beach area). The personnel requirements for this task should amount to no more men (22) than were working on the range during the operational period.

E. COST ESTIMATE

For purposes of a cost estimate, the job classifications and hourly rates reflect those at Interstate Electronics Corporation. No burden rates have been applied. Both outside contract costs and material costs represent the best estimate currently available.

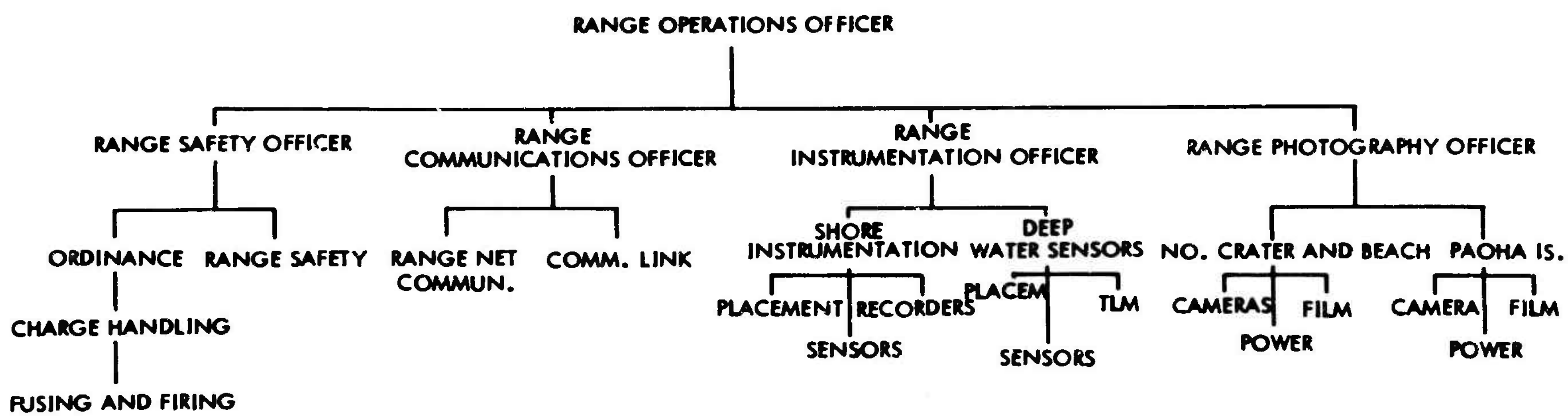


Figure 56. Operations Command Chart

1. Direct Labor Costs

(a) Project Direction-Management and Report Preparation

Category	Time (hours)	Amount
(1) Program Manager	500	$ 3,750.00
(2) Mechanical Supervisor	180	941.00
(3) Electrical Supervisor	320	1,949.00
(4) Field Engineer	100	525.00
(5) Oceanographer	250	1,095.00
(6) Lab Technician	200	600.00
(7) Expediter	400	1,300.00
(8) Clerk Typist	400	1,000.00
(9) Publications Personnel	300	1,125.00
	Subtotal	$12,285.00

(b) Instrumentation Systems

Category	Time (hours)	Amount
(1) Electronics Engineer	340	$ 2,071.00
(2) Mechanical Engineer	360	1,883.00
(3) Mechanical Designer, Sr.	320	1,741.00
(4) Draftsman	80	328.00
(5) Electronics Technician	1088	3,862.00
(6) Mechanical Technician	800	2,656.00
(7) Machinist	1000	4,100.00
	Subtotal	$16,641.00

(c) Trailer Instrumentation

Category	Time (hours)	Amount
(1) Electronics Engineer	710	$ 4,323.00
(2) Draftsman	170	697.00
(3) Electronics Technician	980	3,479.00
(4) Assembler	400	1,036.00
	Subtotal	$ 9,535.00

(d) Charge Support System

Category	Time (hours)	Amount
(1) Mechanical Engineer	60	$ 314.00
(2) Mechanical Designer, Sr.	20	109.00
	Subtotal	$ 423.00

(e) Mobilization, Range Operations and Rollup

Category	Time (hours)	Amount
(1) Electronics Engineer	1760	$12,707.00
(2) Assoc. Electronics Engineer	800	3,784.00
(3) Mechanical Engineer	2480	12,970.00
(4) Field Engineer	820	4,305.00
(5) Oceanographic Technician	800	2,696.00
(6) Field Technician	6480	17,366.00
(7) Electronics Technician	3520	12,496.00
(8) Planner	80	420.00
(9) Photographer (IEC)	1040	5,200.00
	Subtotal	$71,944.00

2. Material and Miscellaneous

Material, Sensor System	$ 80,940.00
Material, Instrument Trailer	23,760.00
Material, Beach Stabilization	5,500.00
Explosive Units	40,000.00
Material, Charge Support	4,000.00
Material, Range Mobilization	20,223.00
Contract Services, Charge Support	1,000.00
Contract Services and Equipment Rental, Range Operations	70,653.00
Telephone and Telegraph, Lee Vining Communications and Mailing	4,000.00
Packing and Shipping	2,800.00
Photographic Supplies	2,040.00
Miscellaneous Costs, Range Operations	5,000.00
Transportation	8,000.00
Publication Materials and Services	2,000.00
Incentive Pay	14,389.00
Miscellaneous Costs	5,000.00
	$289,305.00

3. Totals, Direct Labor

(a) Project Direction-Management and Report Preparation		\$ 12,285.00
(b) Instrumentation Systems		16,641.00
(c) Trailer Instrumentation		9,535.00
(d) Charge Support System		423.00
(e) Range Operations		71,944.00
	Total Direct Labor	\$110.828.00

4. Total, Direct Labor and Material

(a) Direct Labor		\$110,828.00
(b) Material and Miscellaneous		289,305.00
	TOTAL	\$400,133.00

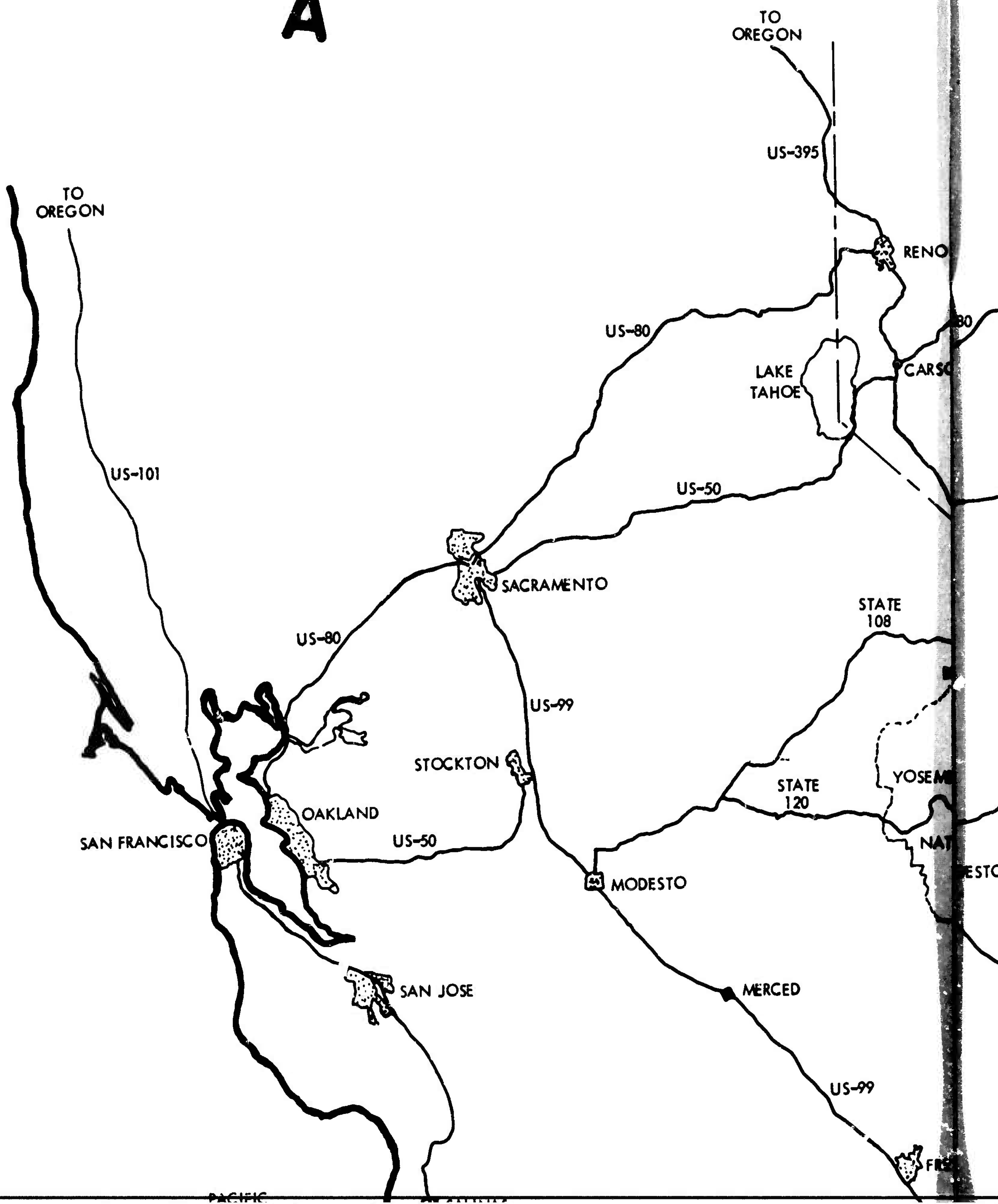
In addition to the above, the following items have been assumed to be Government Furnished Equipment:

(1) 40 Pontoons, 5' x 7' x 5'
(2) Aircraft Landing Mats, pierced steel, 269 ft^2
(3) Vehicles: 2 - Jeeps
1 - 3/4-Ton Truck
1 - 5/8-Ton Truck
(4) 1 Mobile Machine Shop
(5) 1 3/4-Ton Raised Dock
(6) 2 Propulsion Units, 165 hp to 225 hp
(7) 100,000 lbs HBX delivered to NAD, Hawthorne, Nevada
(8) Helicopter

It should be pointed out that some of the equipment in the cost estimate might also be GFE (i.e., Fastax cameras, etc.); however, as their availability for the program execution cannot be determined at this time, their cost was included in the estimate.

The above total represents the best cost estimate for conducting a range instrumentation and operation at Mono Lake, California. No overhead, G & A or fee has been applied to the cost estimate.

A



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SAN FRANCISCO
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MODESTO
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MERCED
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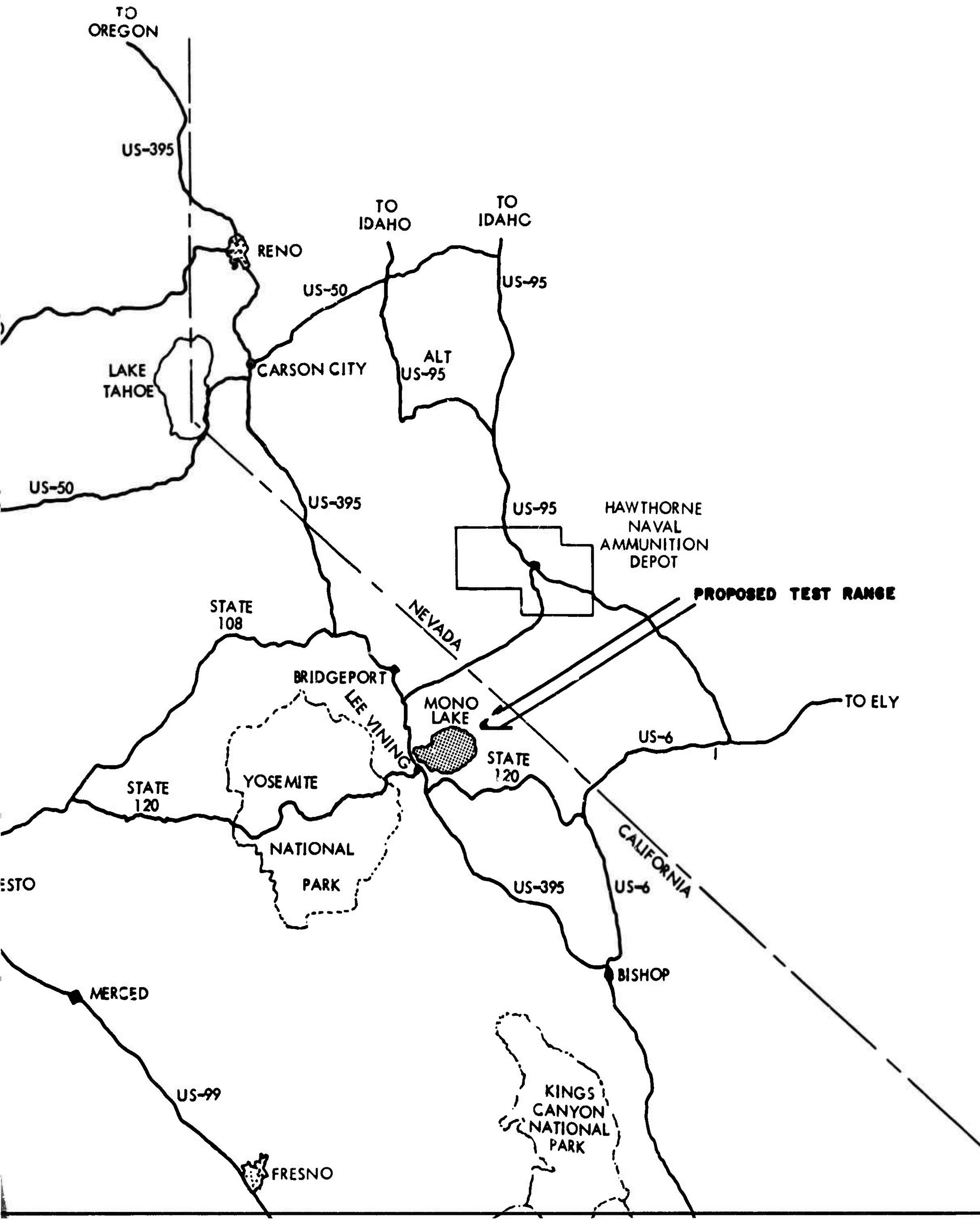
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ALT US-95
LAKE TAHOE
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HAWTHORNE NAVAL AMMUNITION DEPOT
PROPOSED TEST RANGE
STATE 108
NEVADA
BRIDGEPORT
LEE VINING
MONO LAKE
TO ELY
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STATE 120
YOSEMITE
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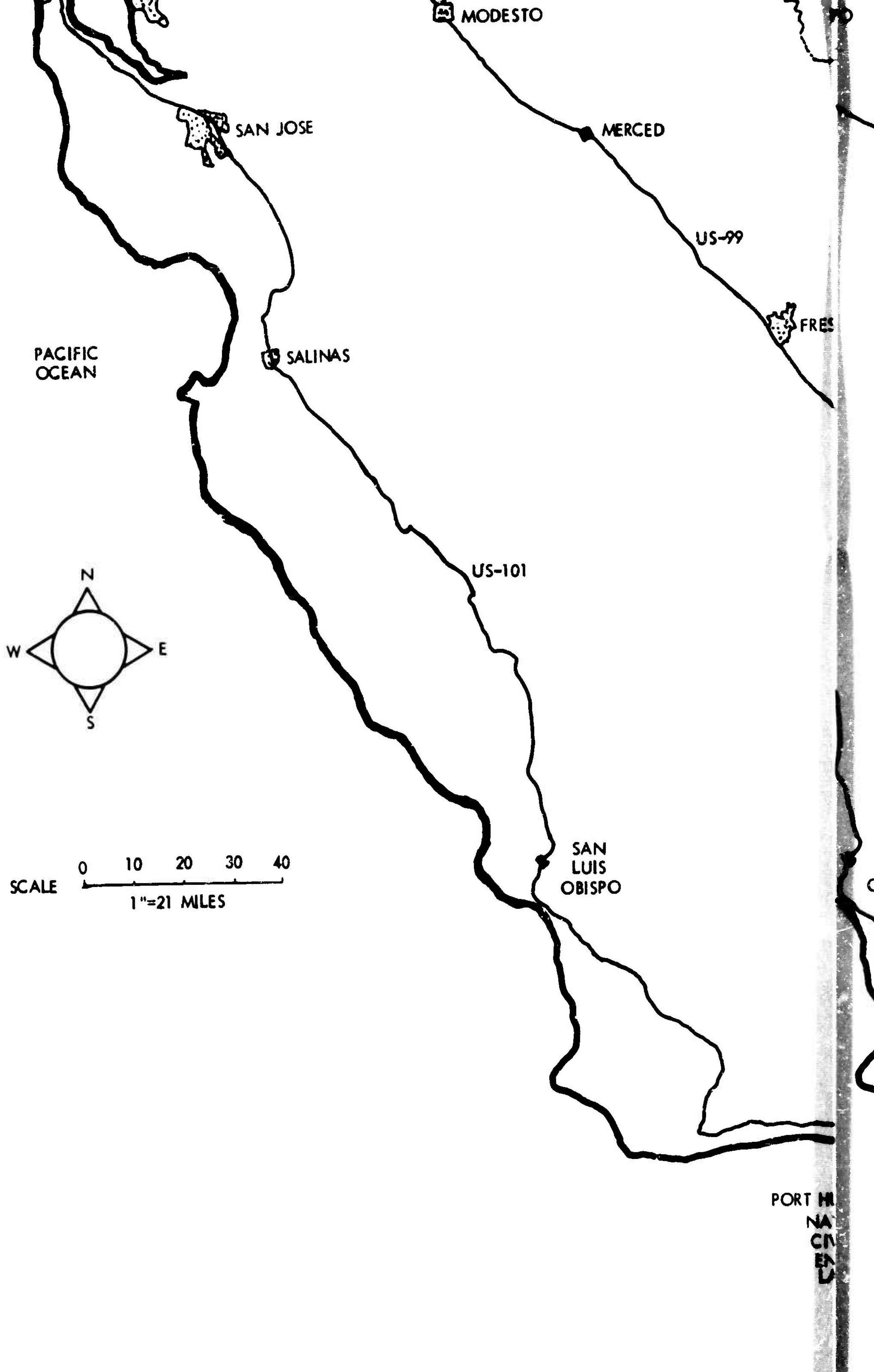
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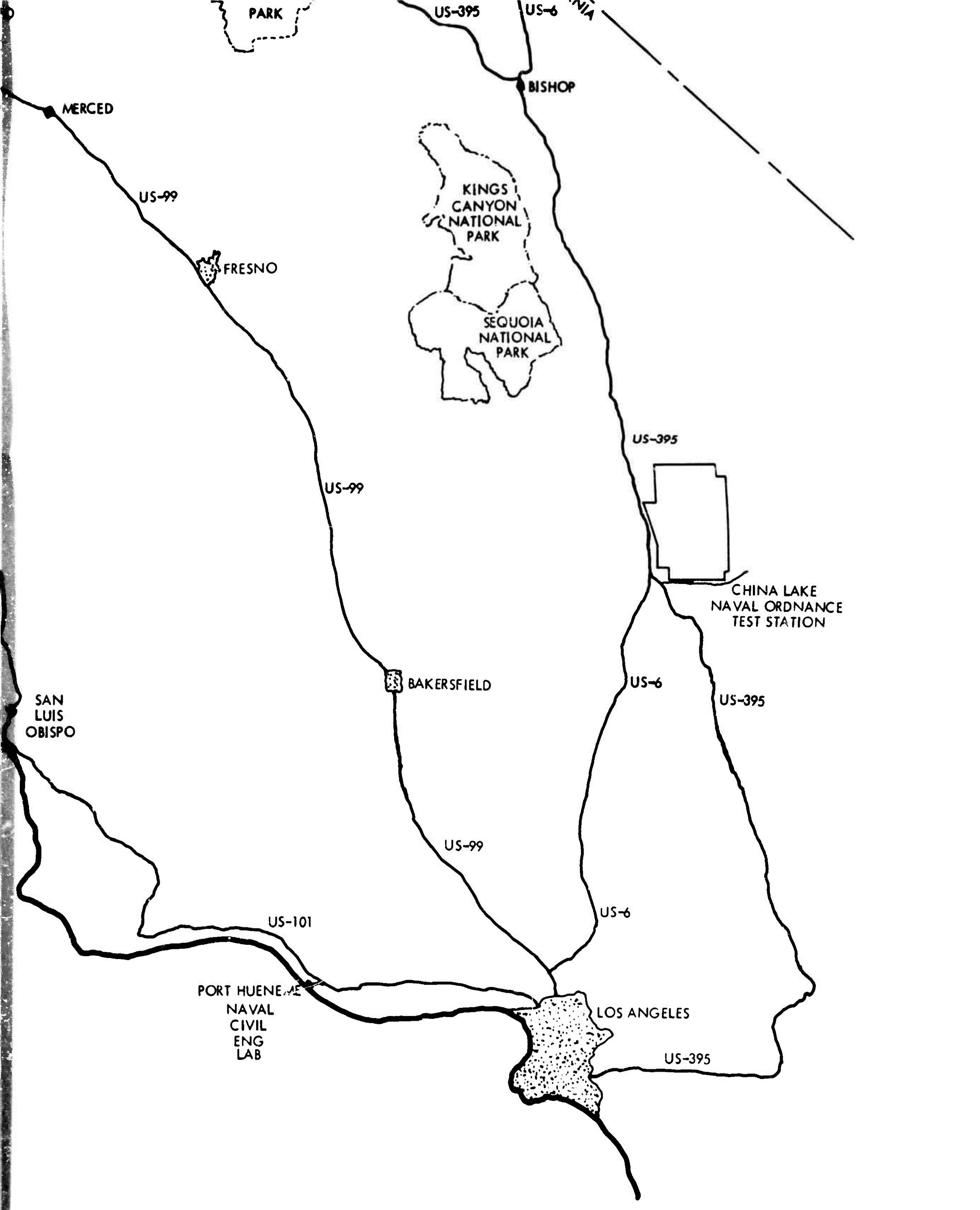
FIGURE 1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SEQUOIA
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US-99
CHINA LAKE
NAVAL ORDNANCE
TEST STATION
SAN
LUIS
OBISPO
BAKERSFIELD
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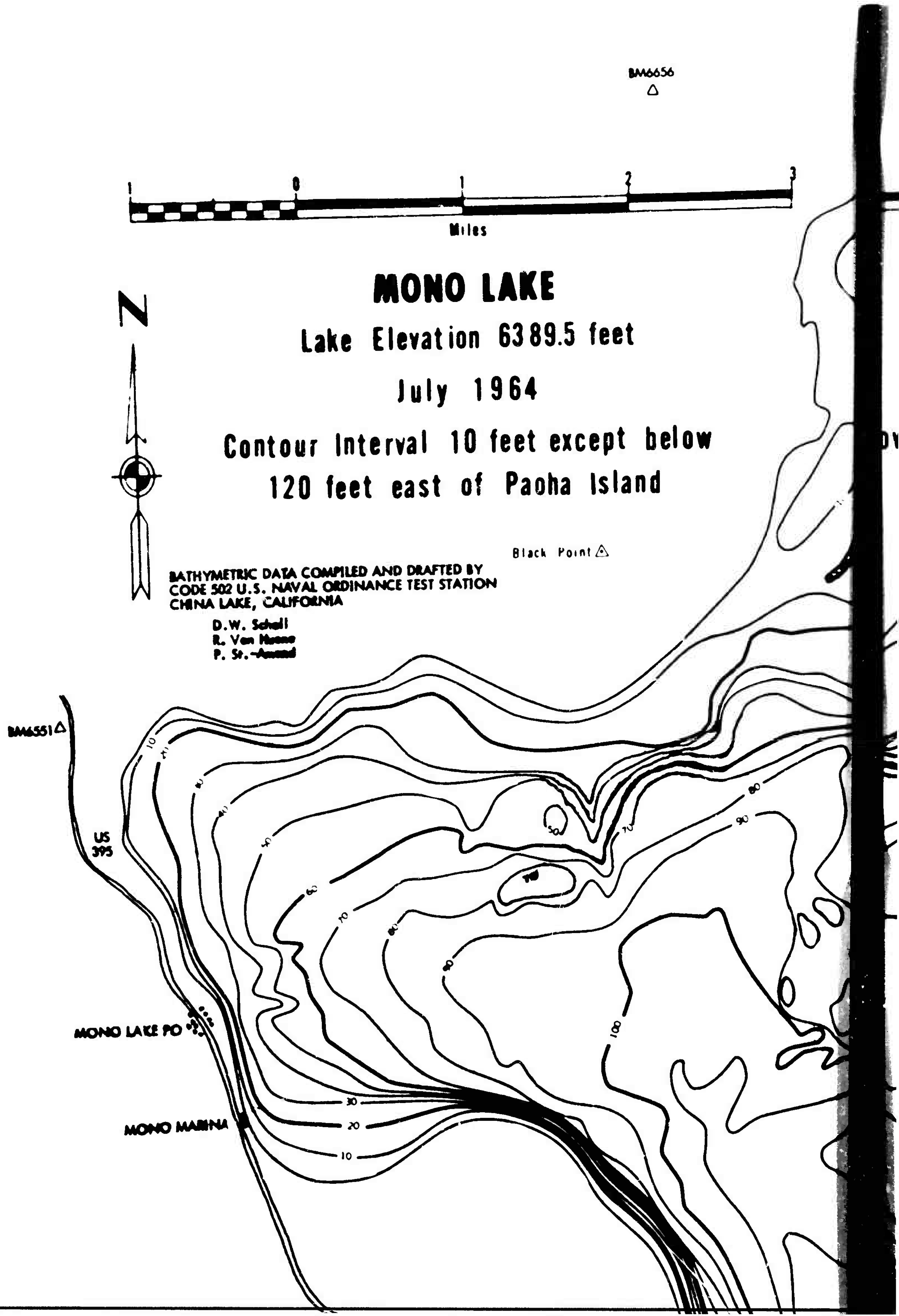
FIGURE I


BM6656
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Miles
MONO LAKE
Lake Elevation 6389.5 feet
July 1964
Contour Interval 10 feet except below
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N
Black Point
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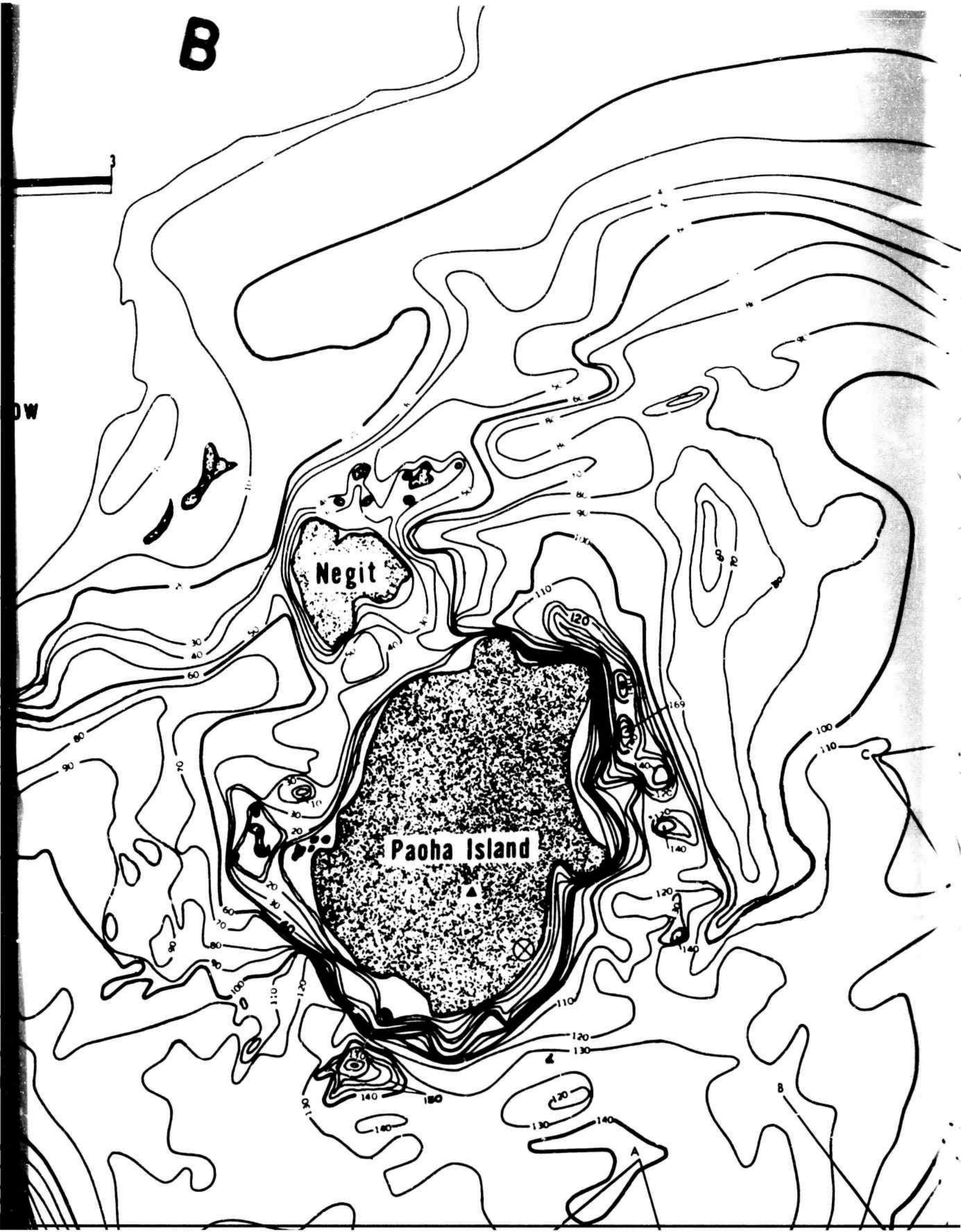
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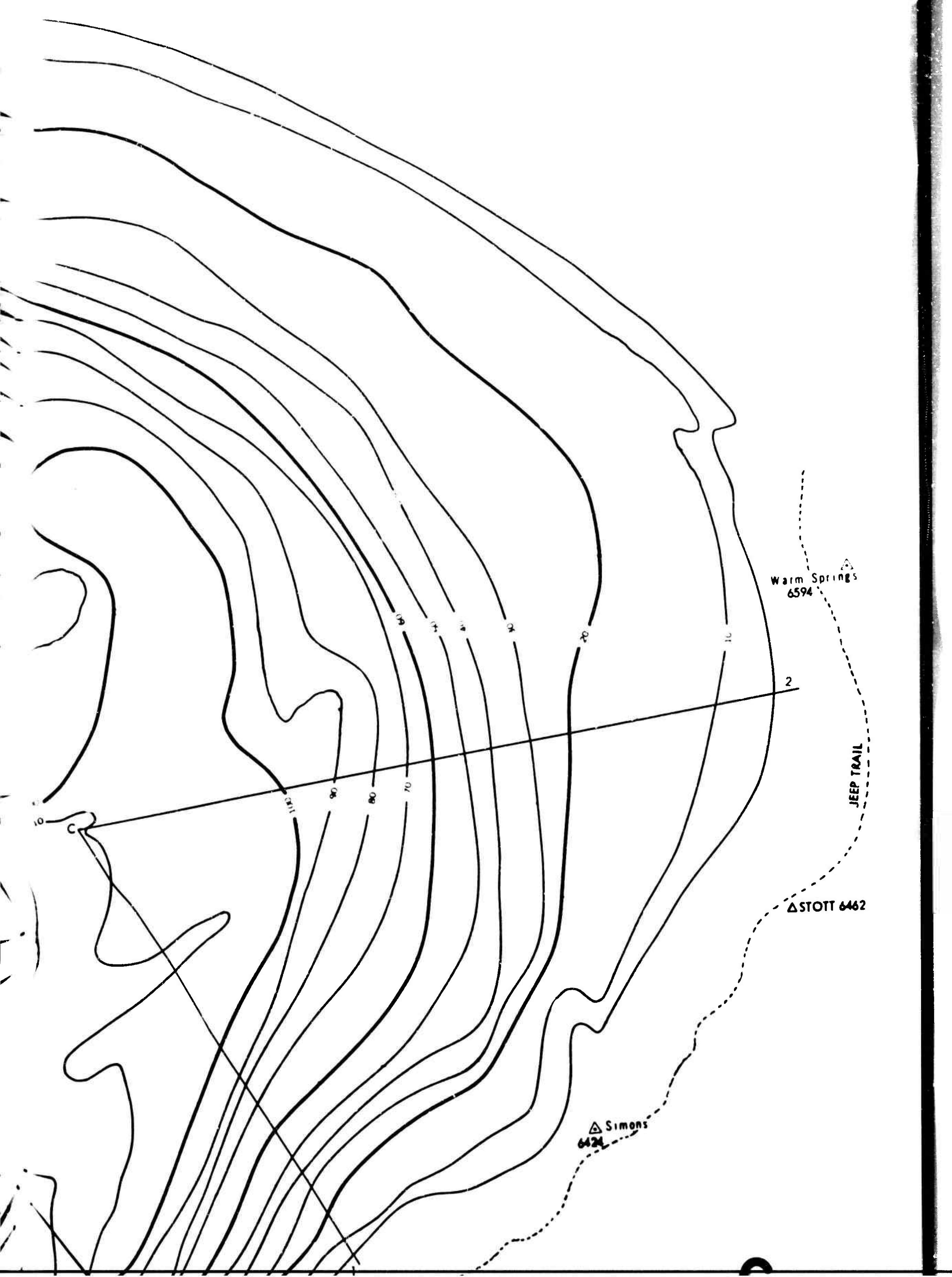

Warm Springs
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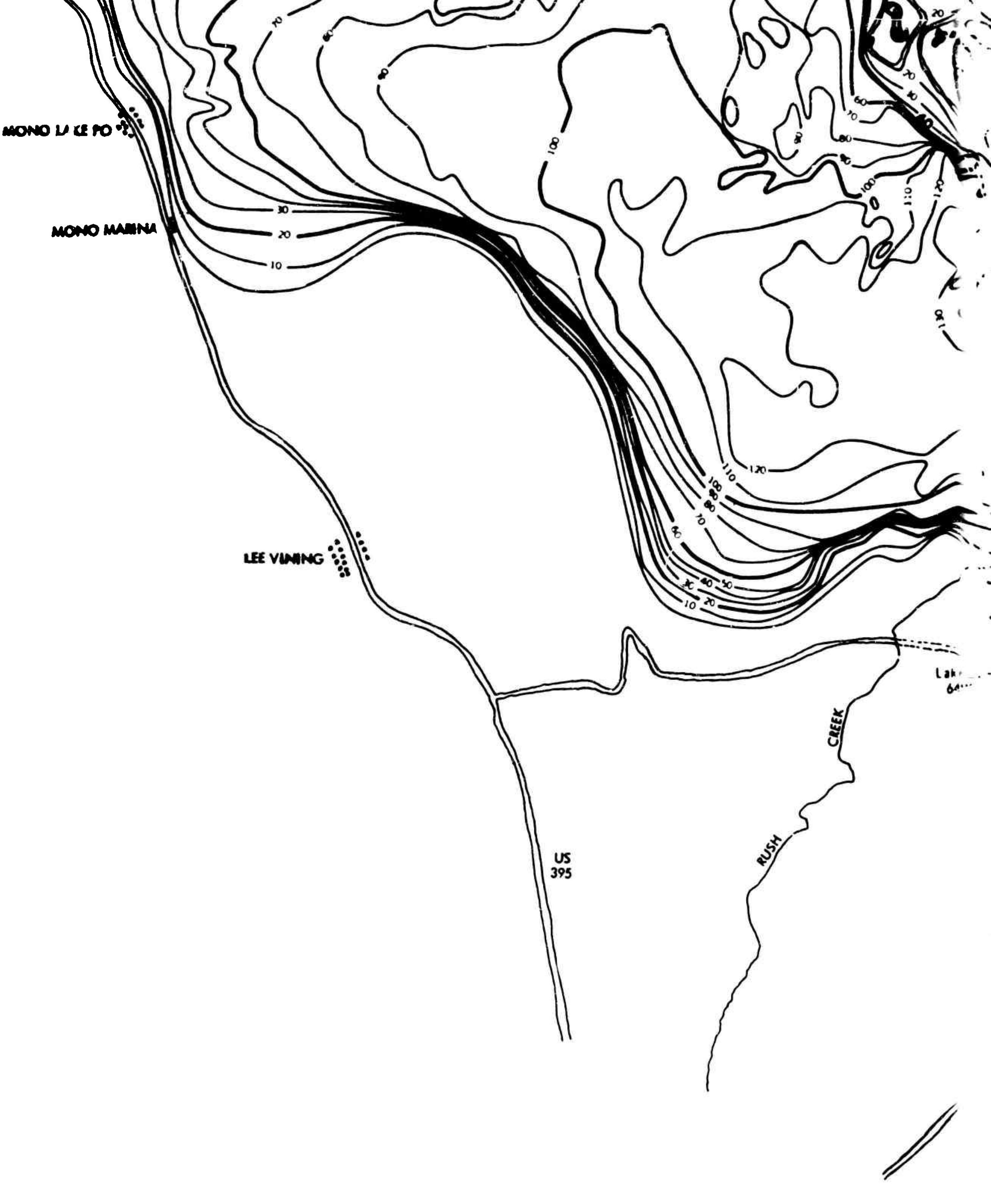
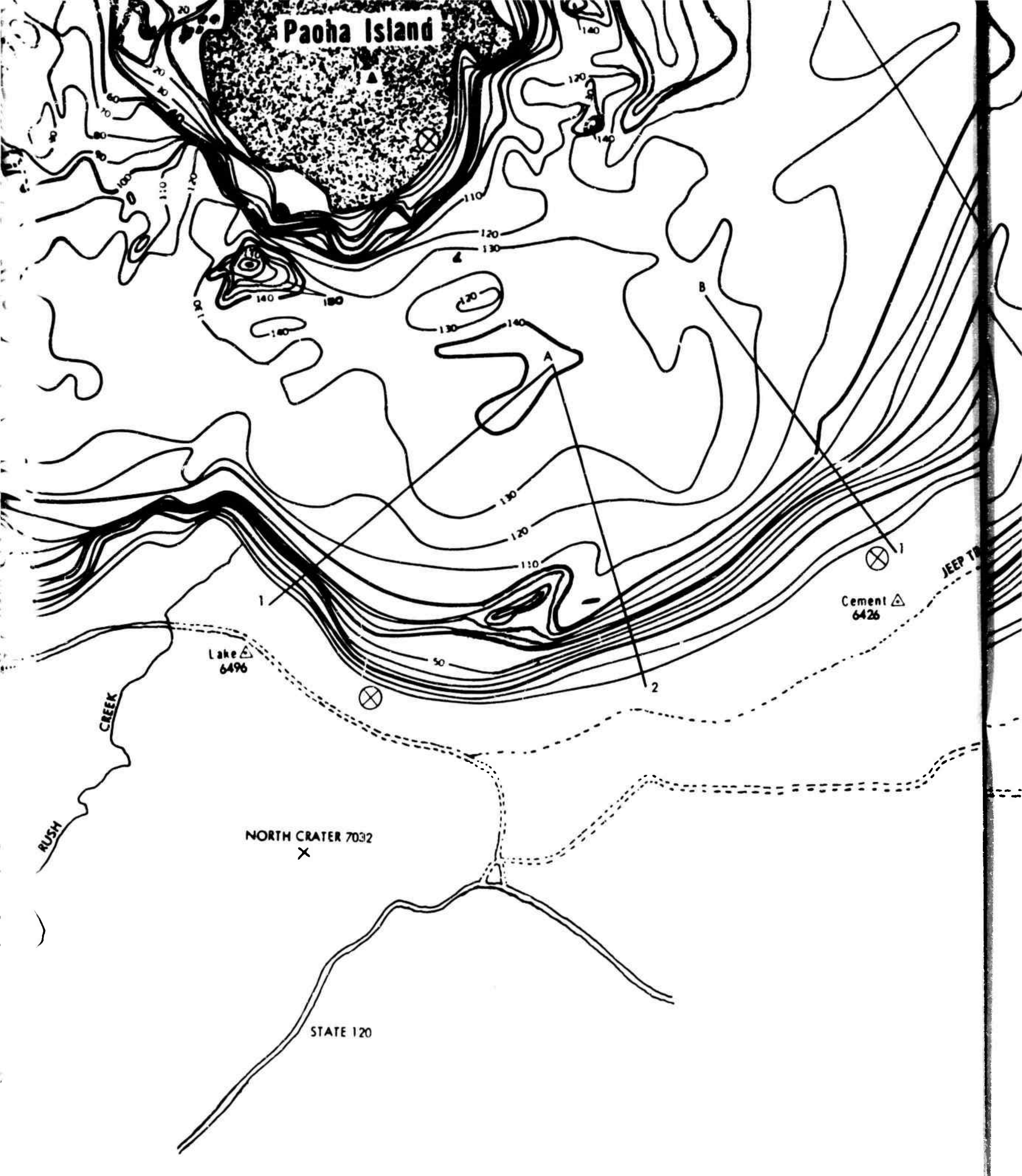


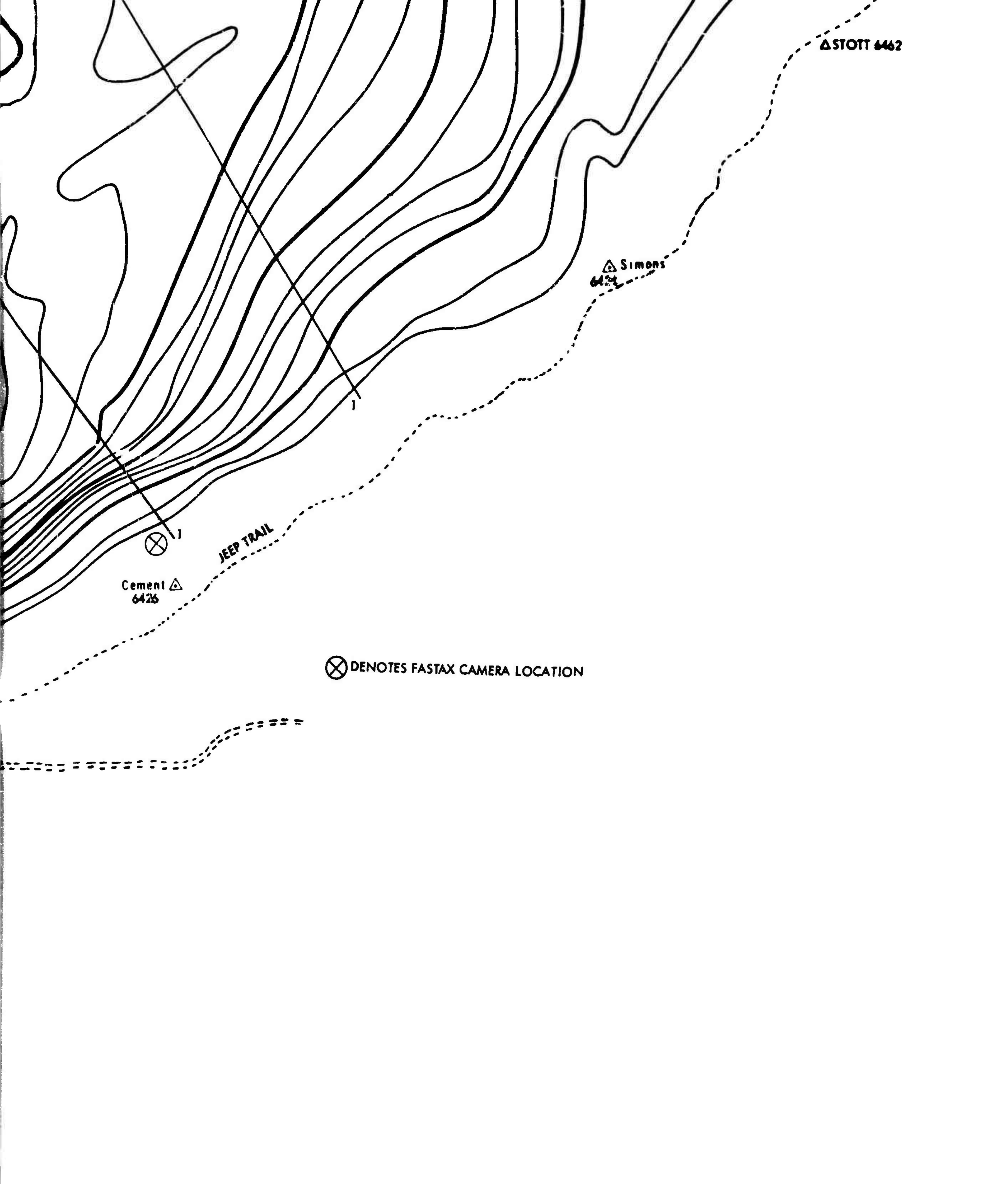
FIG

D



E

FIGURE 3 BOTTOM TOPOGRAPHY PROFILE TRANSITS, FASTAX CAMERA LOCATIONS, MONO LAKE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JEEP TRAIL
Cement
6426
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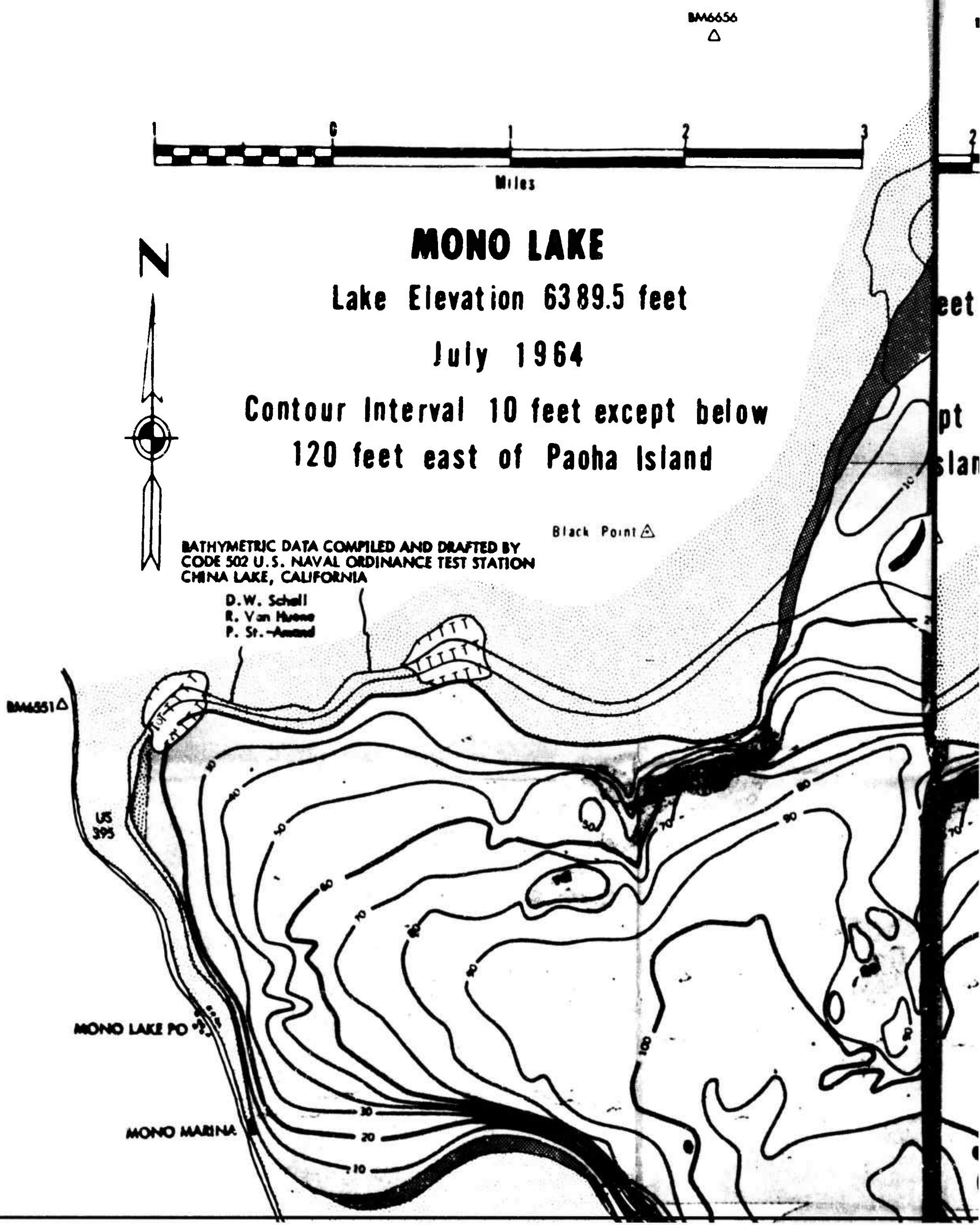
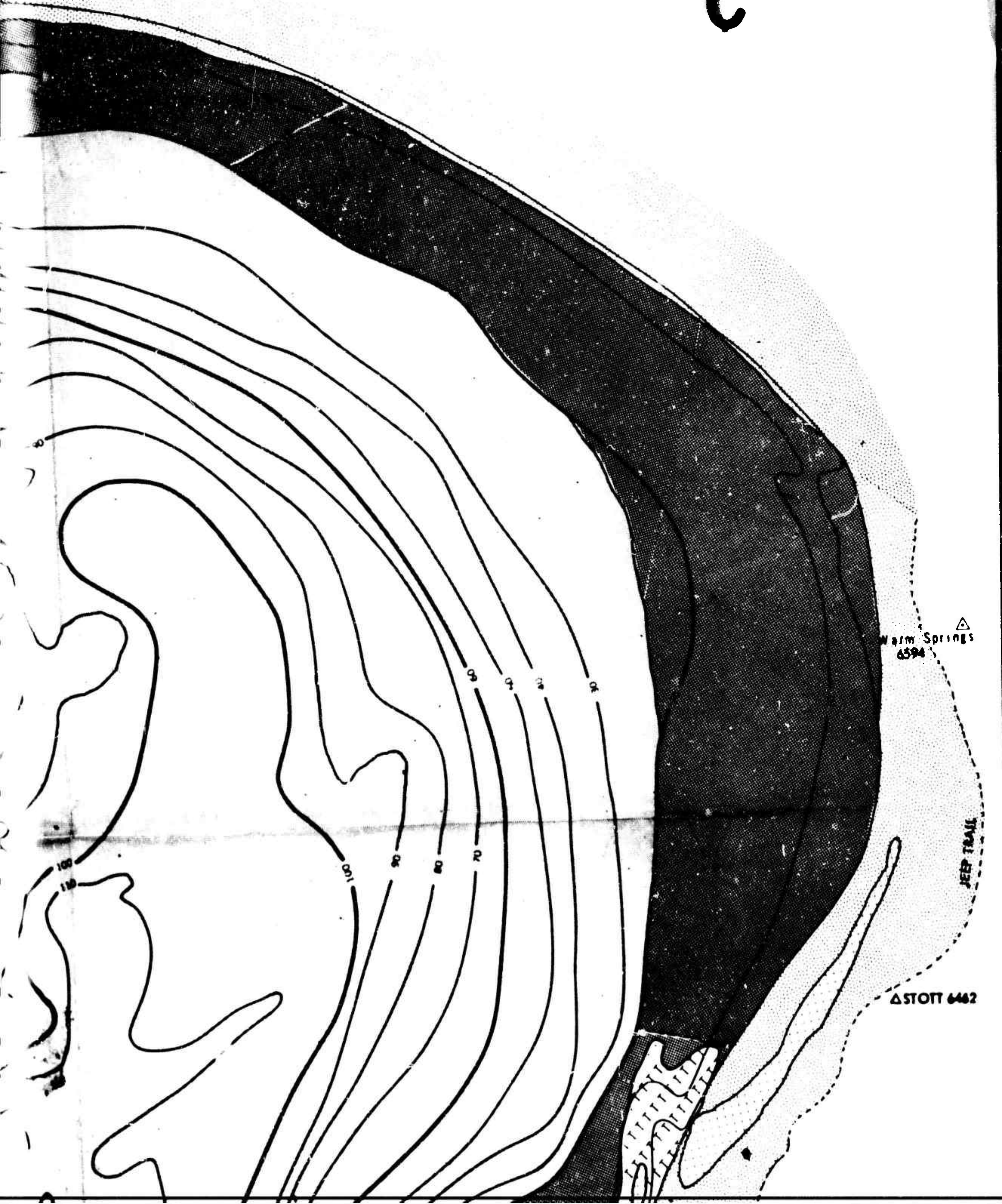
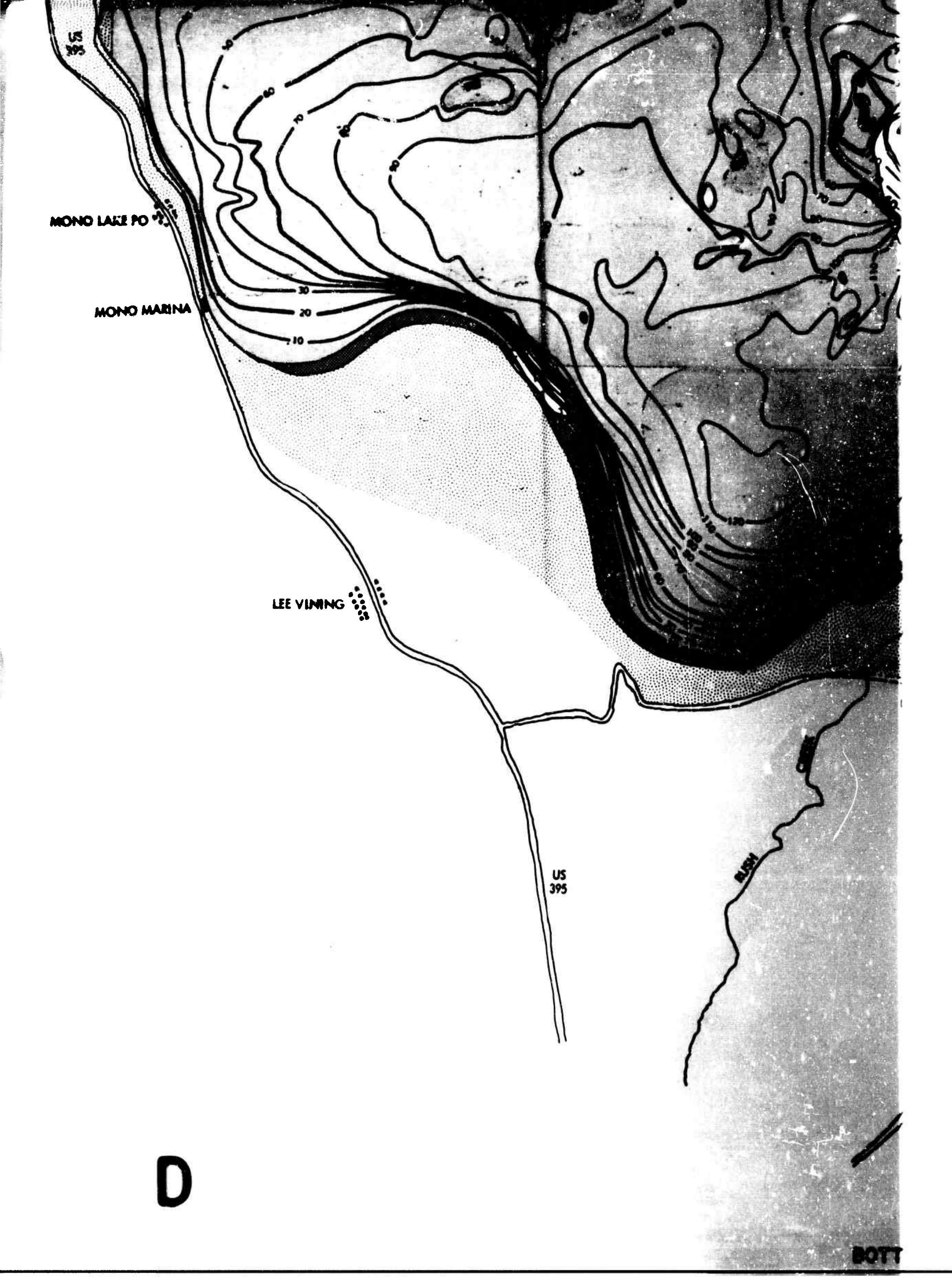

BM6656
Miles
MONO LAKE
Lake Elevation 6389.5 feet
July 1964
Contour Interval 10 feet except below
120 feet east of Paoha Island
N
Black Point
BATHYMETRIC DATA COMPILED AND DRAFTED BY
CODE 502 U.S. NAVAL ORDINANCE TEST STATION
CHINA LAKE, CALIFORNIA
D.W. Schell
R. Van Huene
P. St.-Amand
BM6551
US
395
MONO LAKE PO
MONO MARINA


B
BM6656
2
3
eet
pt below
land
Negit
Paoha Island
10
20
30
40
50
60
70
80
90
100
110
120
130
140
169

C




US
395
MONO LAKE PO
MONO MARINA
30
20
10
LEE VINING
US
395
RUSH
CREEK
D
BOTT

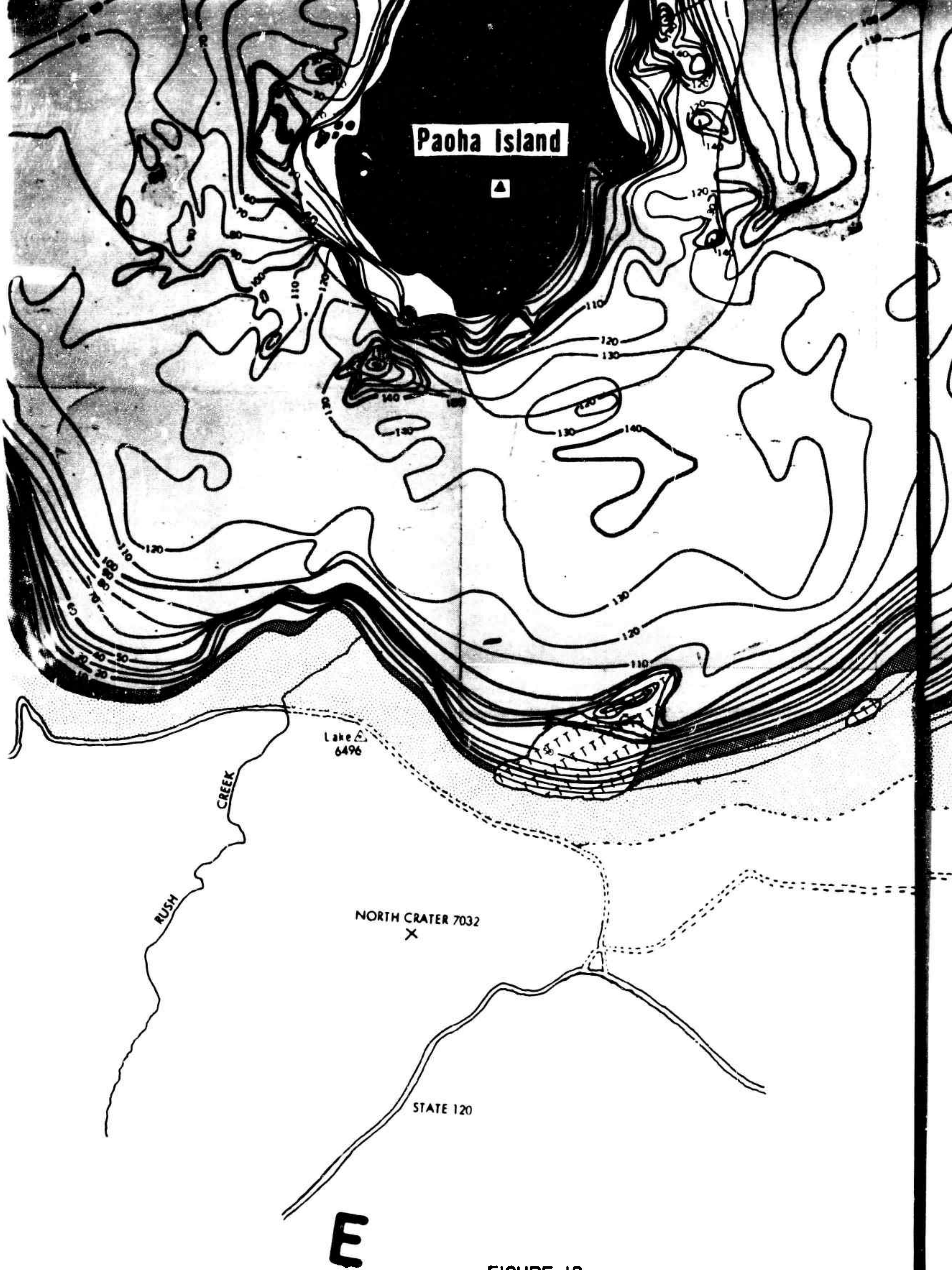
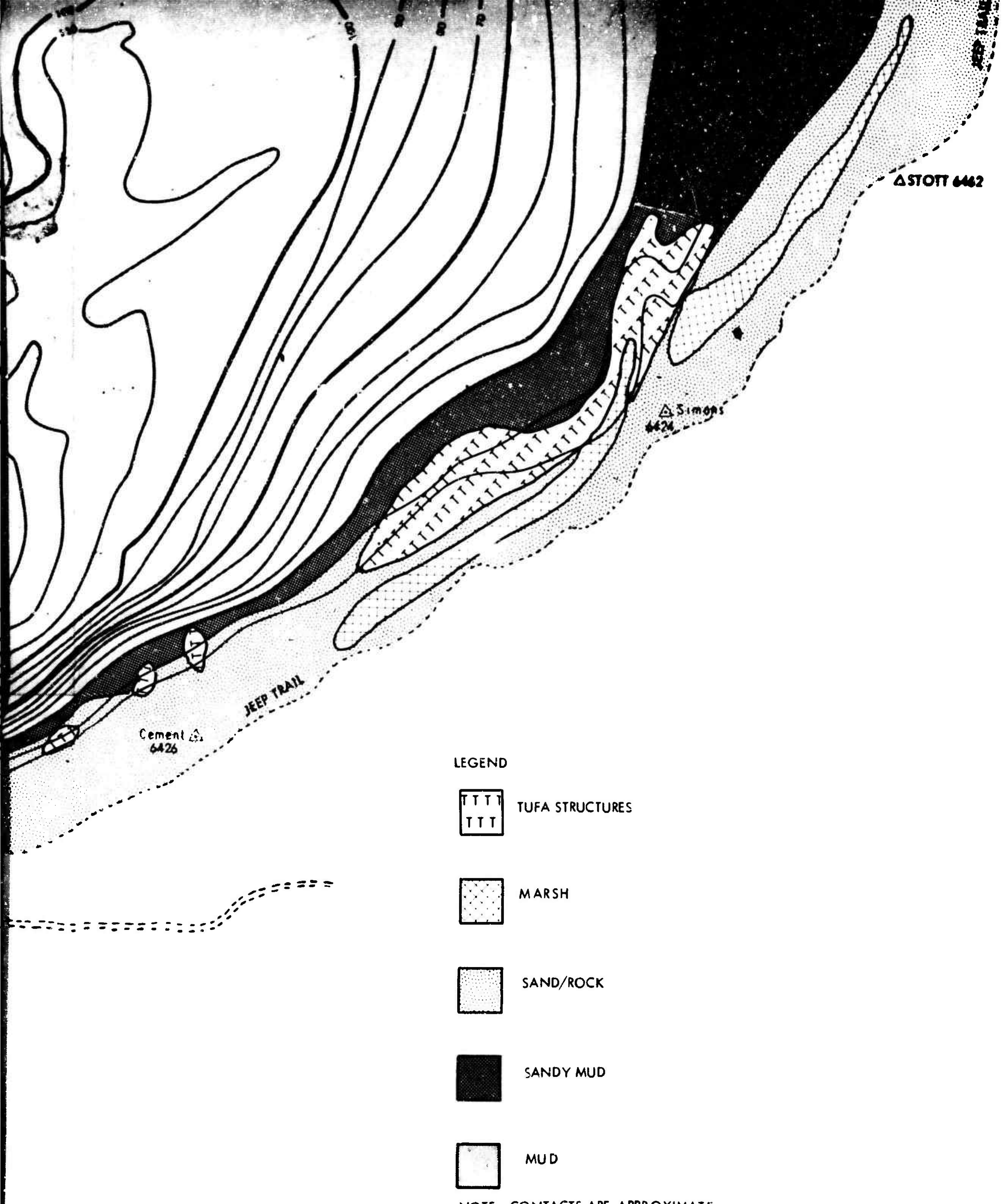


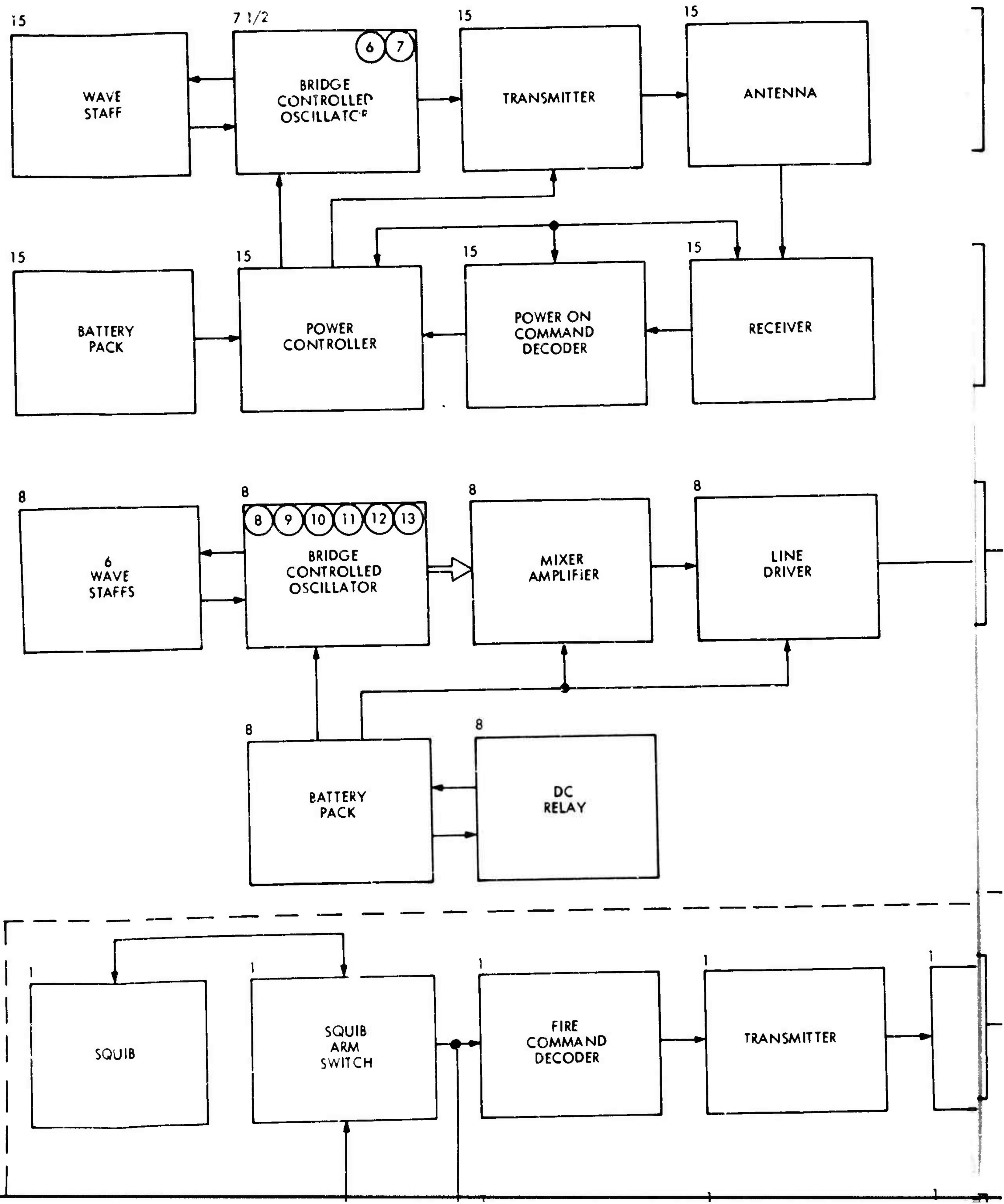
FIGURE 18

BOTTOM AND SHORELINE SEDIMENTS, MONO LAKE


STOTT 6462
Simons
6424
JEEP TRAIL
Cement
6426
LEGEND
TUFA STRUCTURES
MARSH
SAND/ROCK
SANDY MUD
MUD
NOTE: CONTACTS ARE APPROXIMATE

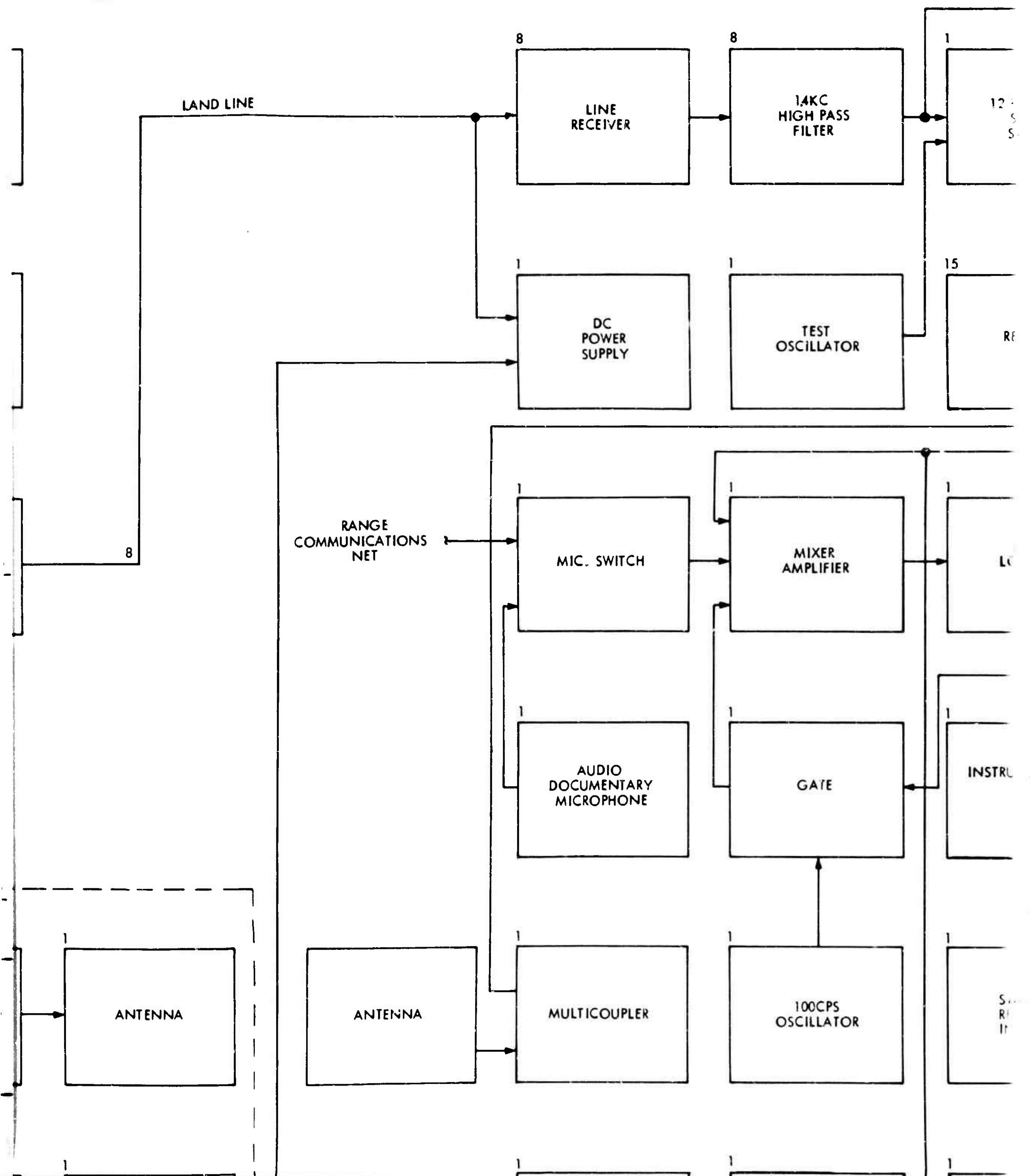
F

A



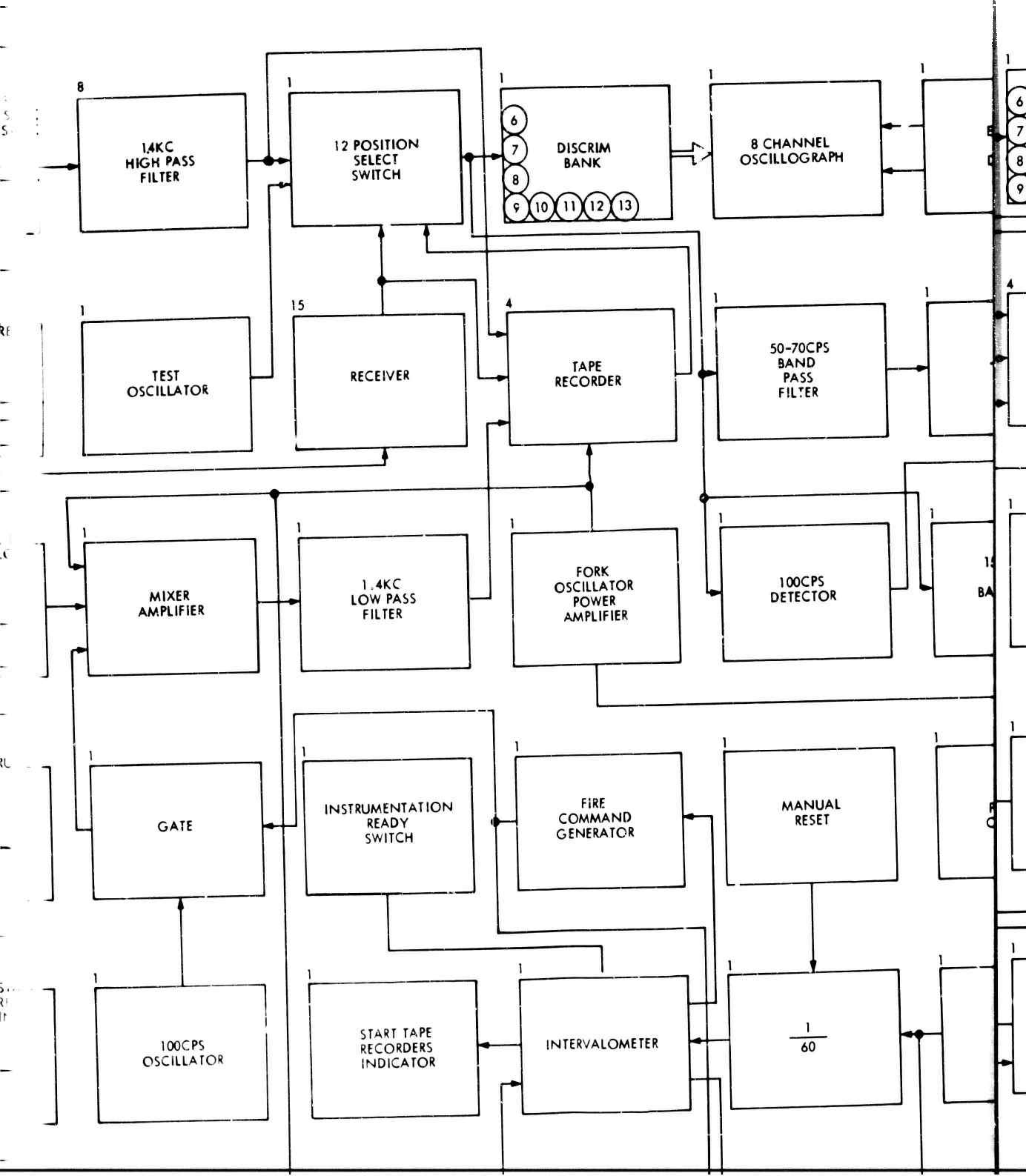
15
WAVE STAFF
7 1/2
6
7
BRIDGE CONTROLLED OSCILLATOR
15
TRANSMITTER
15
ANTENNA
15
BATTERY PACK
15
POWER CONTROLLER
15
POWER ON COMMAND DECODER
15
RECEIVER
8
6 WAVE STAFFS
8
8
9
10
11
12
13
BRIDGE CONTROLLED OSCILLATOR
8
MIXER AMPLIFIER
8
LINE DRIVER
8
BATTERY PACK
8
DC RELAY
1
SQUIB
1
SQUIB ARM SWITCH
1
FIRE COMMAND DECODER
1
TRANSMITTER
1

B

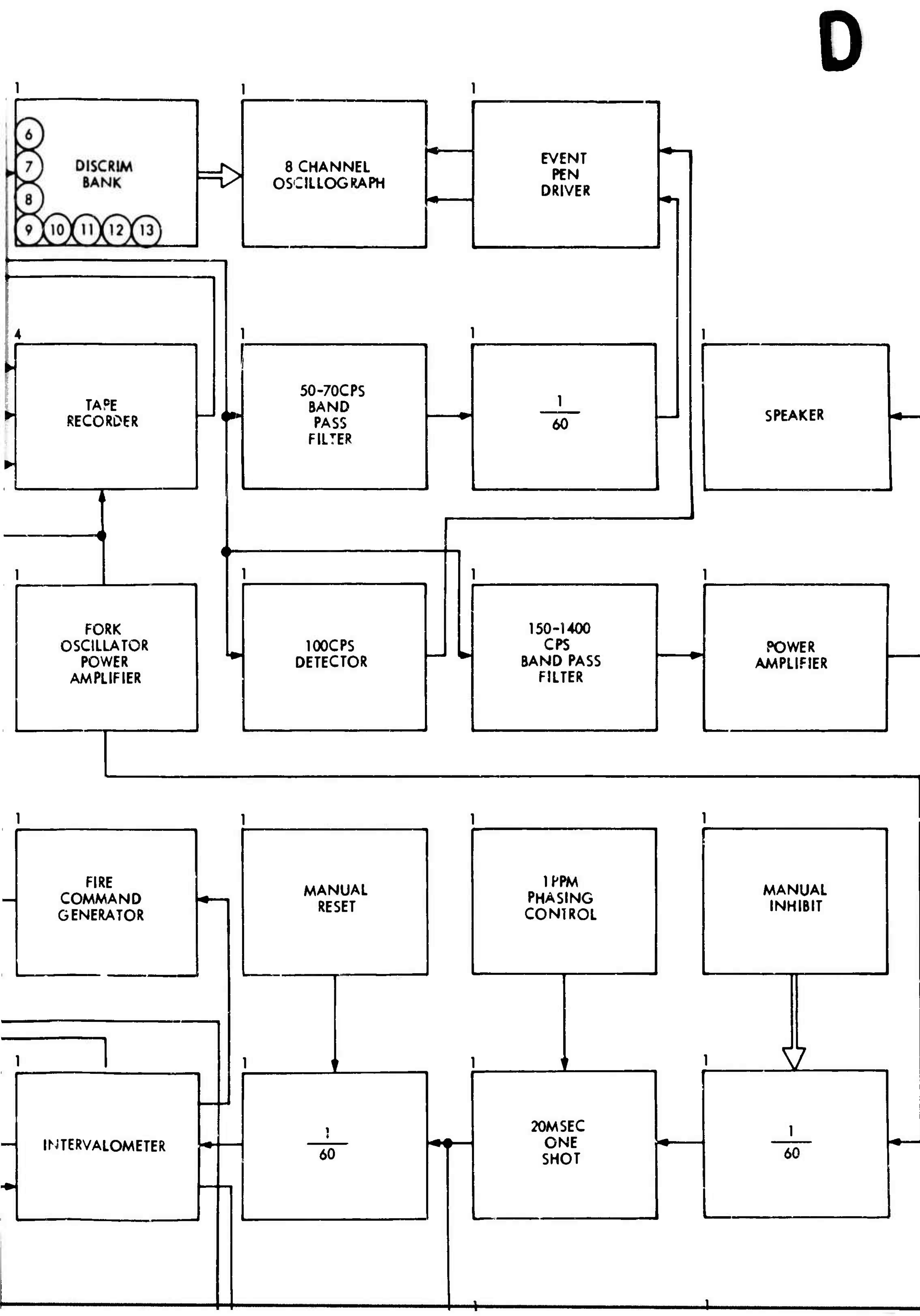


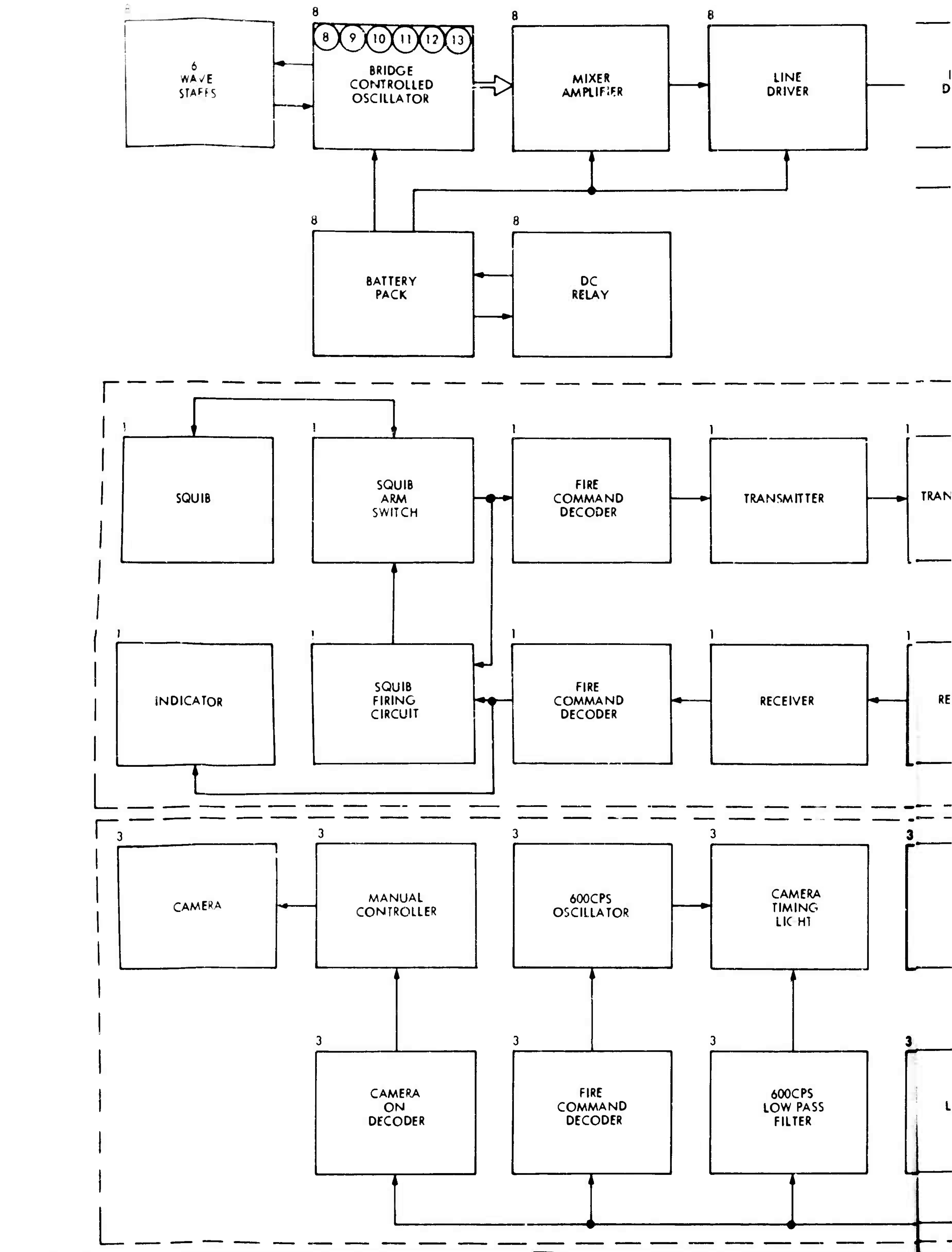
LAND LINE
8
LINE RECEIVER
8
1.4KC HIGH PASS FILTER
1
DC POWER SUPPLY
1
TEST OSCILLATOR
15
RANGE COMMUNICATIONS NET
1
MIC. SWITCH
1
MIXER AMPLIFIER
1
AUDIO DOCUMENTARY MICROPHONE
1
GATE
ANTENNA
ANTENNA
MULTICOUPLER
100CPS OSCILLATOR

C

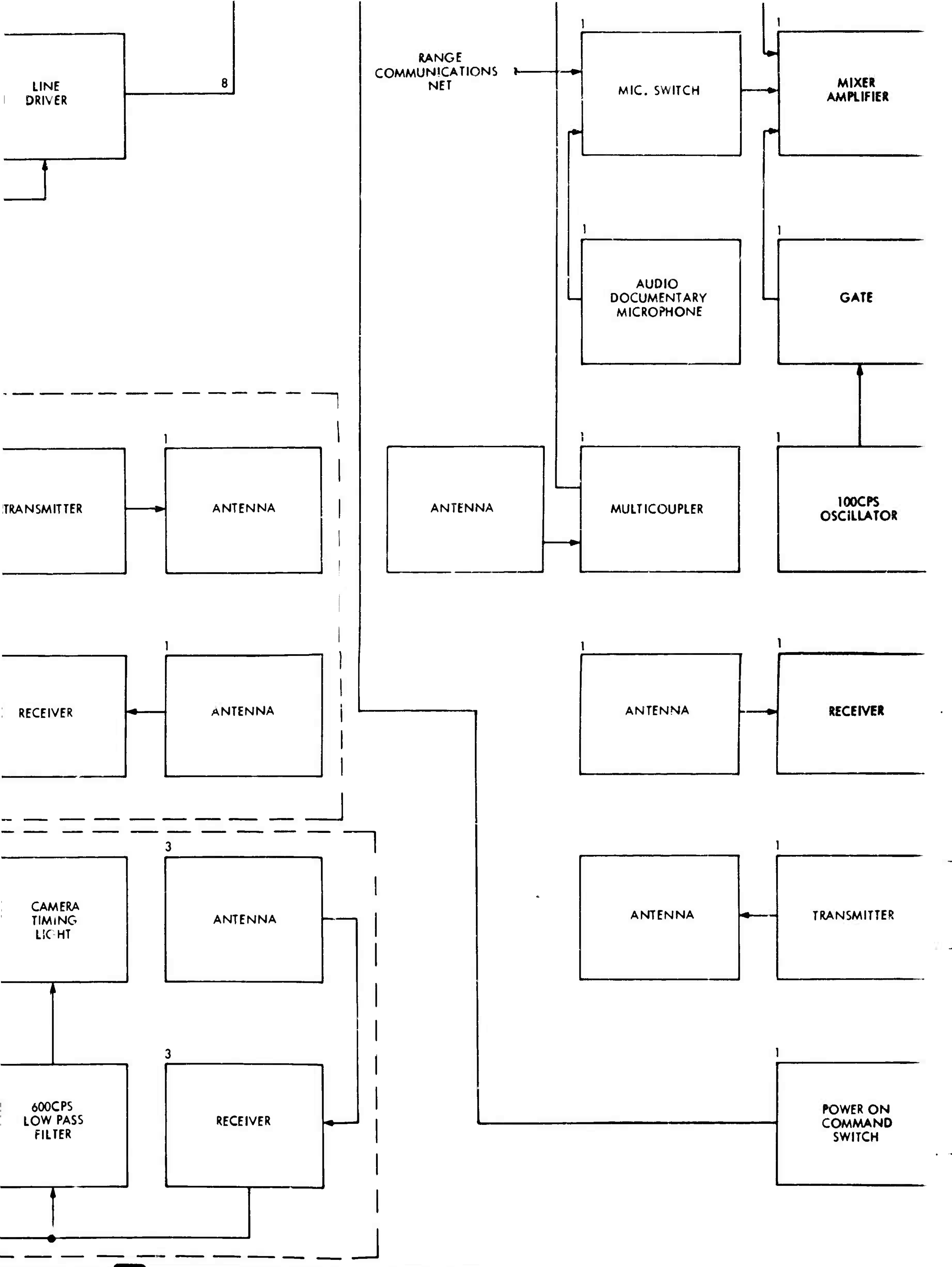


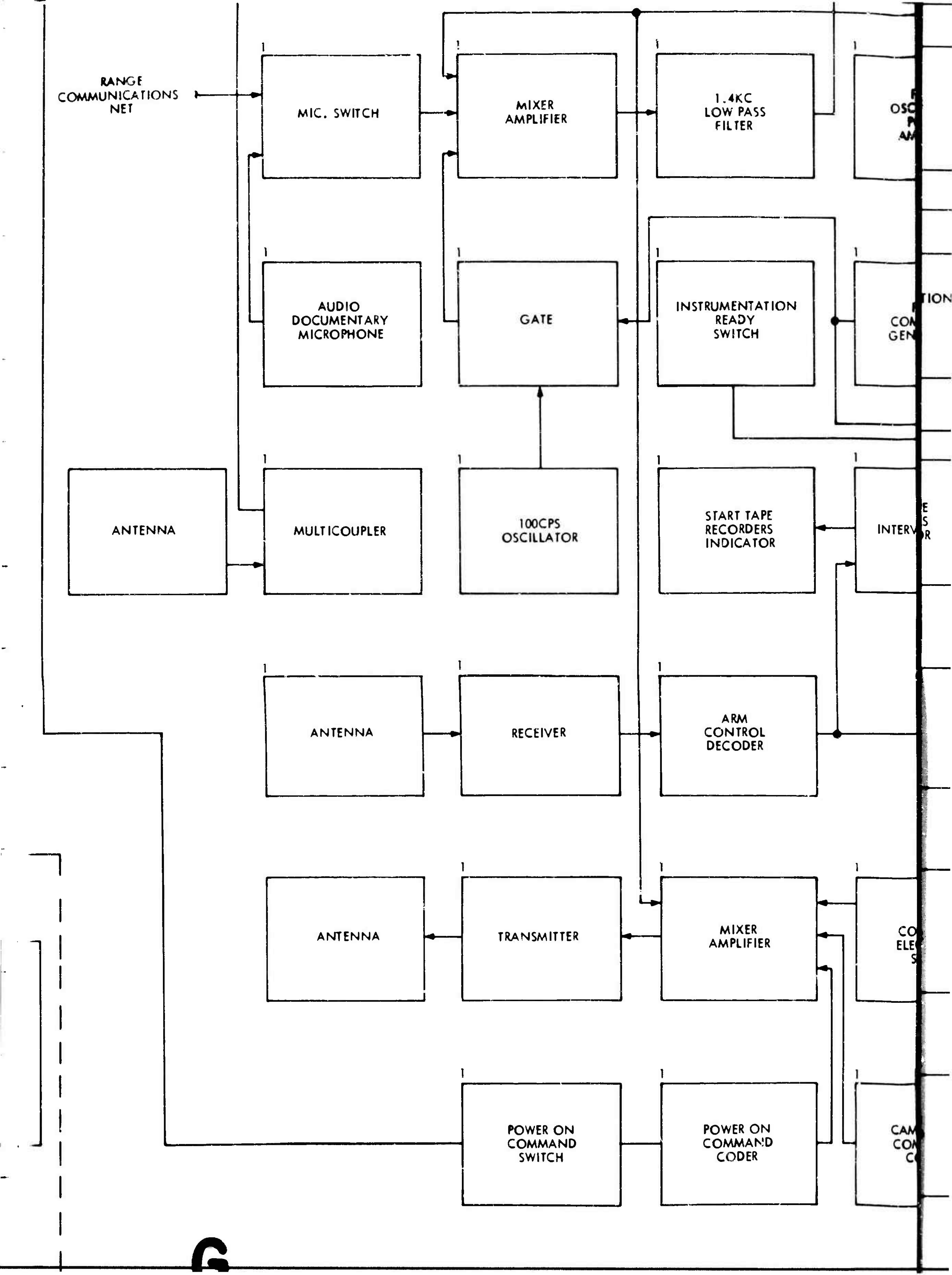
1.4KC HIGH PASS FILTER
12 POSITION SELECT SWITCH
DISCRIM BANK
6
7
8
9
10
11
12
13
8 CHANNEL OSCILLOGRAPH
TEST OSCILLATOR
RECEIVER
TAPE RECORDER
50-70CPS BAND PASS FILTER
MIXER AMPLIFIER
1.4KC LOW PASS FILTER
FORK OSCILLATOR POWER AMPLIFIER
100CPS DETECTOR
GATE
INSTRUMENTATION READY SWITCH
FIRE COMMAND GENERATOR
MANUAL RESET
100CPS OSCILLATOR
START TAPE RECORDERS INDICATOR
INTERVALOMETER
1/60


D
DISCRIM BANK
6
7
8
9
10
11
12
13
8 CHANNEL OSCILLOGRAPH
EVENT PEN DRIVER
TAPE RECORDER
50-70CPS BAND PASS FILTER
1/60
SPEAKER
FORK OSCILLATOR POWER AMPLIFIER
100CPS DETECTOR
150-1400 CPS BAND PASS FILTER
POWER AMPLIFIER
FIRE COMMAND GENERATOR
MANUAL RESET
1 PPM PHASING CONTROL
MANUAL INHIBIT
INTERVALOMETER
1/60
20MSEC ONE SHOT
1/60



6 WAVE STAFFS
BRIDGE CONTROLLED OSCILLATOR
8 9 10 11 12 13
MIXER AMPLIFIER
LINE DRIVER
BATTERY PACK
DC RELAY
SQUIB
SQUIB ARM SWITCH
FIRE COMMAND DECODER
TRANSMITTER
INDICATOR
SQUIB FIRING CIRCUIT
FIRE COMMAND DECODER
RECEIVER
CAMERA
MANUAL CONTROLLER
600CPS OSCILLATOR
CAMERA TIMING LIGHT
CAMERA ON DECODER
FIRE COMMAND DECODER
600CPS LOW PASS FILTER


LINE DRIVER
8
RANGE COMMUNICATIONS NET
MIC. SWITCH
MIXER AMPLIFIER
AUDIO DOCUMENTARY MICROPHONE
GATE
TRANSMITTER
ANTENNA
ANTENNA
MULTICOUPLER
100CPS OSCILLATOR
RECEIVER
ANTENNA
ANTENNA
RECEIVER
CAMERA TIMING LIGHT
ANTENNA
ANTENNA
TRANSMITTER
600CPS LOW PASS FILTER
RECEIVER
POWER ON COMMAND SWITCH



RANGE COMMUNICATIONS NET
MIC. SWITCH
MIXER AMPLIFIER
1.4KC LOW PASS FILTER
AUDIO DOCUMENTARY MICROPHONE
GATE
INSTRUMENTATION READY SWITCH
ANTENNA
MULTICOUPLER
100CPS OSCILLATOR
START TAPE RECORDERS INDICATOR
ANTENNA
RECEIVER
ARM CONTROL DECODER
ANTENNA
TRANSMITTER
MIXER AMPLIFIER
POWER ON COMMAND SWITCH
POWER ON COMMAND CODER

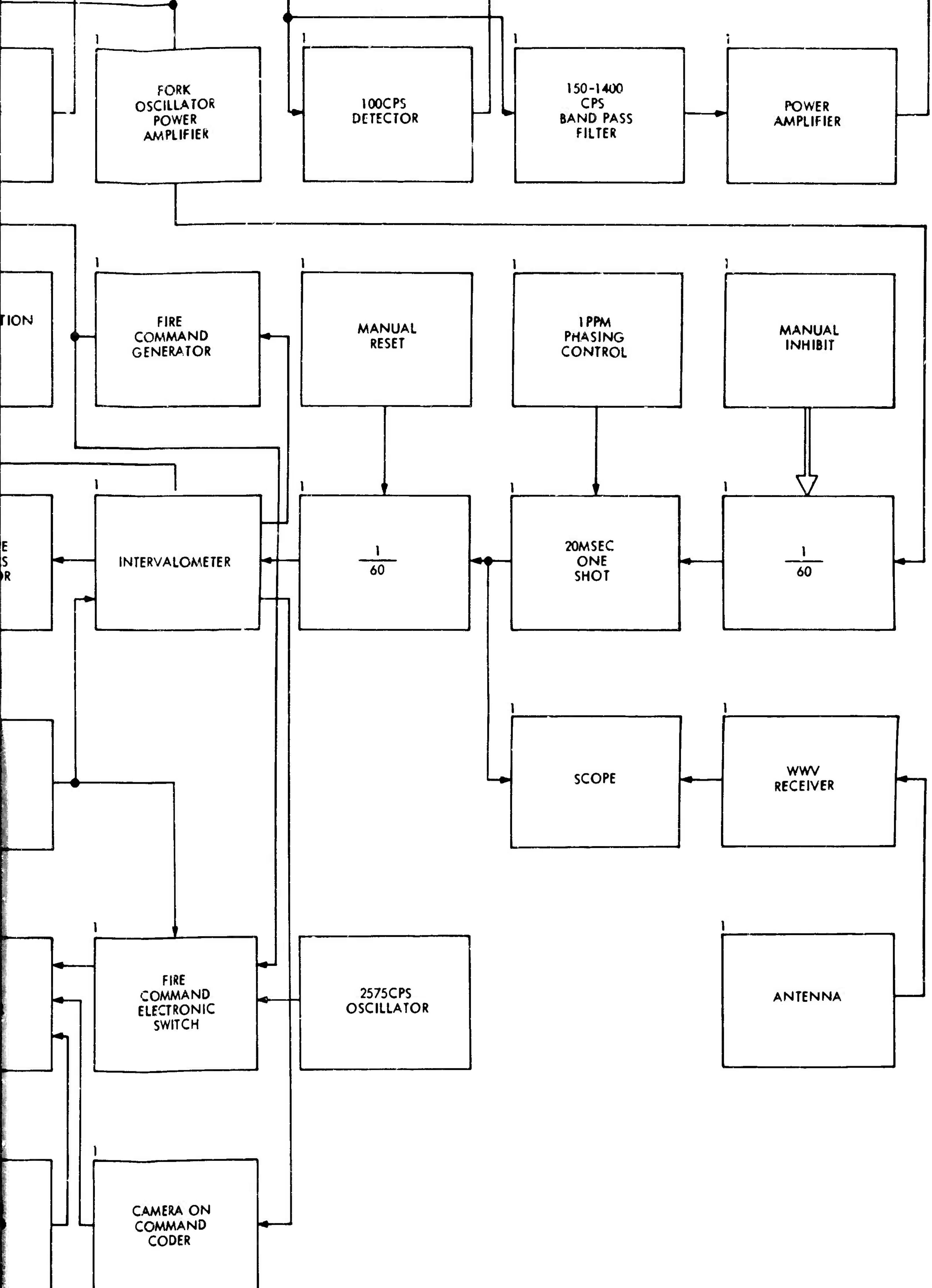


FIGURE 33
SYSTEM BLOCK DIAGRAM

H

MD 620 408

ERRATA SHEET for Final Report

MONO LAKE WAVE EXPERIMENT: FEASIBILITY STUDY

Page 13	Figure 8	Change occurence to occurrence
Page 14	Figure 9, 10	Change occurence to occurrence
Page 15	Figure 11, 12	Change occurence to occurrence
Page 16	Figure 13, 14	Change occurence to occurrence
Page 20	Figure 19	Change occurence to occurrence
Page 21	Figure 20, 21	Change occurence to occurrence
Page 22	Figure 22, 23	Change occurence to occurrence
Page 23	Figure 24, 25	Change occurence to occurrence
Page 25	4th paragraph Line 2	Change airplane to aircraft
Page 44	Figure 40	Add BALLAST w/arrow to base of float. Change 3-1/2 lbs. to 3.5 lbs.

Page 46 Insert after paragraph "For small angular displacements . . . . becomes Ba."

For a slender rod rotating about an axis at one end of the rod and perpendicular to the rod axis, the mass moment of inertia is:

$$J = \frac{ML^2}{3}$$

Page 47	Line 6	Change respresents to represents.
Page 48	Equation 5	Change $W\frac{1}{3}$ to $W^{1/3}$